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On the Relationship between the Nitrogen Deficiency of the Rice Plant Roots and the Reduction of the Medium

Hideo OKAJIMA

(Received on December 10, 1958)

I. Introduction

In the course of some study on the root nutrition, on the basis of ecological and physiological aspect, author recognized the phenomenon that reducing power of nitrogen deficient rice plant roots was vigorous, while its oxidation power was weak. The findings that cereals roots had reduction power to the rhizosphere and activity of this root function increased with plant growth, reaching maximum around flowering stage, have been reported by Mitsui et al.[4)5)]

However, if the reduction power of roots becomes great under nitrogen deficient condition, the variation of nitrogen nutritive conditions of plant with growth may be taken into consideration as the cause of the intensified reduction of the medium at a particular stage of plant growth. In this paper, this possibility is reported with some root function of nitorgen deficient rice plant.

II. Experimental Method

Having fixed 2 individuals of Fujisaka No. 5 seedlings in a 5 *l*-pot after growing in the germination bed in the previous report,[1)] water culture was carried out on June 7, 1956 according to the experimental plan in Table 1. The culture solution was prepared with the composition in the pievious report[1)], and NH_4NO_3 was employed as nitrogen source. Replacement of the solution was in principle made once a week. In addition, rice plants were sampled during the course of

Table 1. Name of experiment series.

Name of series	Remarks
−N+N	No nitorgen until July 14. After then, nitrogen was supplied until the maturing stage
+N−N	Nitrogen was not supplied after July 14.
+N+N	Nitrogen was supplied throughout the experimental period.

note : (12 mg N per pot was given unil June 28, during period of preparation for exmination)

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growth for the below-listed investigation.

Investigation Item :

1. H_2S was detected by the colorimetric method with p-amino-dimethylaniline[2], and NO_2-N was analyzed by the Griess' method.

2. Classification of root

Individual roots which constituted the root system were classified into A,B,B_1 and C types[note 1] according to morphological distinction of each root, length of which was measured respectively. The dry weight of roots and number of roots by classified were expressed with the average value of individual numbers subject to the present investigation (5 plants at the early stage of growth and 3 plants at later stage of growth.)

A type : Young roots which developed about one week after root formation, with a small number of lateral roots and elasticity.

B type : Healthy roots, remarkable in the formation of lateral roots and presented white colur in the basal part although somewhat lignified.

B_1 type : Colored roots among the roots of B type, turned into brown partially.

C type: Old roots, colored wholly and inelastic.

3. Determination of oxidation or reduction power of roots

(i) Esculin oxidation (methods of Goto and Tai[6])

(ii) Nitrate reduction (for comparison of NO_2-N formation)

(iii) H_2S oxidation (for comparison of the diminishing degrees by the addition of H_2S to the culture solution.)

For determination of the above-mentioned three examinations, the roots sampled from rice plants at different growth stages were washed carefully and each intact root was placed respecitvely in widemouth bottles contained 500 cc testing solutions, then the oxidizing amount and reducing amount by the respective testing solutions were measured twice at intervals of 6 hours and 24 hours. Being four replications system in one series, the experiment was carried out in the dark room under a constant room temperature (21°C). As regards the concentration of the testing solutions, esculin was 10 ppm and NO_3-N ($NaNO_3$) 30 ppm, H_2S being about 8 ppm of S and pH 5.0.

III. Experimental Results

1. Formation of H_2S and NO_2-N in the culture solution at different growth stages.

According to Fig. 1, the generation of H_2S which had its peak at the heading stage was seen in $+N-N$ series, in which the reduction of the rhizosphere can

Note 1 : For this calssification, the investigation of the amount of oxygen uptake and TTC reaction revealed the tendency of the respiratory function to be $A>B\fallingdotseq B_1>C$, by which the age of roots seems concordant generally with such classification.

be conjectured around the flowering stage of rice plants. This phenomenon, however, was observed only in the series lacking in nitrogen from the young ear formation stage, but the detection of H_2S could not be made in+N+N series under supply of nitrogen throughout the investigation period. In addition, In−N+N series the generation of H_2S took place during the nitrogen deficient period, after which time the generation of H_2S decreased gradually to be stopped in a short time.

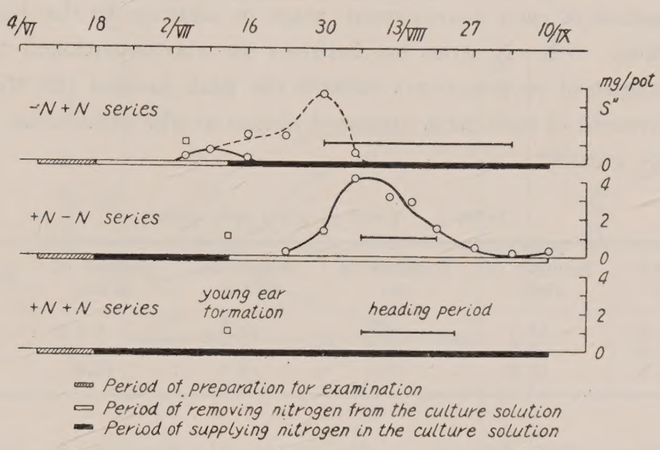

Fig. 1. Generation of H_2S in the culture solution of each series.

The results in Fig. 1 which determined the generation of H_2S by the amount of sulfide-S detected in culture solution, were too qualitative from the traits of hydrogen sulfide to discuss little differentials. However, smell of H_2S was remarkable at S 0.5 mg per pot, and the culture solution and part of the root was converted into black color of iron sulfide over S 2 mg, by which the generation of considerable H_2S was confirmed.

An smell supposedly from oxidized intermediate products of H_2S was always felt before and after the period of H_2S generation in +N−N series and −N+N series where its generation took place, but even the smell of H_2S was not sensed in +N+N series. In consequence, as seen in the results of Fig. 1, the reduction of the culture solution to the extent of the generation of H_2S may not be related particularly with the life cycle but regarded as a phenomenon caused under nitrogen deficient conditions. The portions with a dot line of −N+N series in the figure indicate the generation of H_2S in the exceptional series (−N−N) to which the supply of nitorgen was suspended following the lack in nitrogen at the preceding period.

2. Development of root system in each series

Although the increase ratio of root numbers of rice plants in −N+N series was small at the early stage of growth after the commencement of nitrogen supply, the

number of roots increased steadily until the maturing stage. In this series, tillering took place profusely from the stem elongation stage and the physiological ages of tillers constituting plant were disordered to an extent that the heading period lasted as long as one month. And this series showed the lowest ratio of grains to straws.

Contrary to this series, in +N−N series regulation period of tillers was short and the developement of each stem appeared altogether, and elongation of roots occurred mainly after the stem elongation stage. Thus, the series demonstrated a clear distinction of each development stage in addition to the highest ratio of grains to straws. +N+N series lay between the abovementioned two series, in which the increase of root numbers showed the peak around the stem elongation stage, development of each stem appeared almost at the same time, and the yield of grains was greatest.

Table 2. Yield of plant (per plant).

Name of series	Number of stem	Number of ear	Weight of straw	Weight of grain	grain/straw
−N+N	13.1	8.3	10.6 g	5.4 g	0.50
+N−N	5.7	5.7	5.7	7.9	1.38
+N+N	13.8	8.6	10.7	13.8	1.28

The problem which arises from the relationship between development of rice plants in each series and the reducing condition of culture medium should be the elongation phenomenon of roots which has been frequently pointed out as the characteristic of nitorgen dificient roots.

Fig. 2 illustrates the number of roots in each series and the total length of roots (total length of each root), and N percentage (per dry weight) in roots and their basal part of the stem (the basal part 5 cm above the ground). Firstly, +N−N series which was remarkable in elongation of roots and generation of hydrogen sulfide, shall be described.

N percentage of every part of rice plants such as tillers and roots was reduced as whole by the removal of nitrogen from the culture solution and the basal part of the stem indicated particulary the decrease of total nitrogen together with N percentage and the outflow of nitrogen in the basal part of the stem seen to meet the benefit of each organ for nitrogen after the removing of nitrogen from culture solution.[note 2)] On that occasion, the amount of nitrogen in the root system which obtained from the basal part of the stem approximated 3 mg, most of which was considered to be consumed for formation of new roots. The reason is that the

Note 2 : As the basal part of the stem was most characteristic quantitatively on the occasion of the redistribution of nitrogen, N percentages of roots and the basal part of the stem were entered jointly, but the relation with each organ above the ground shall be reported separately.

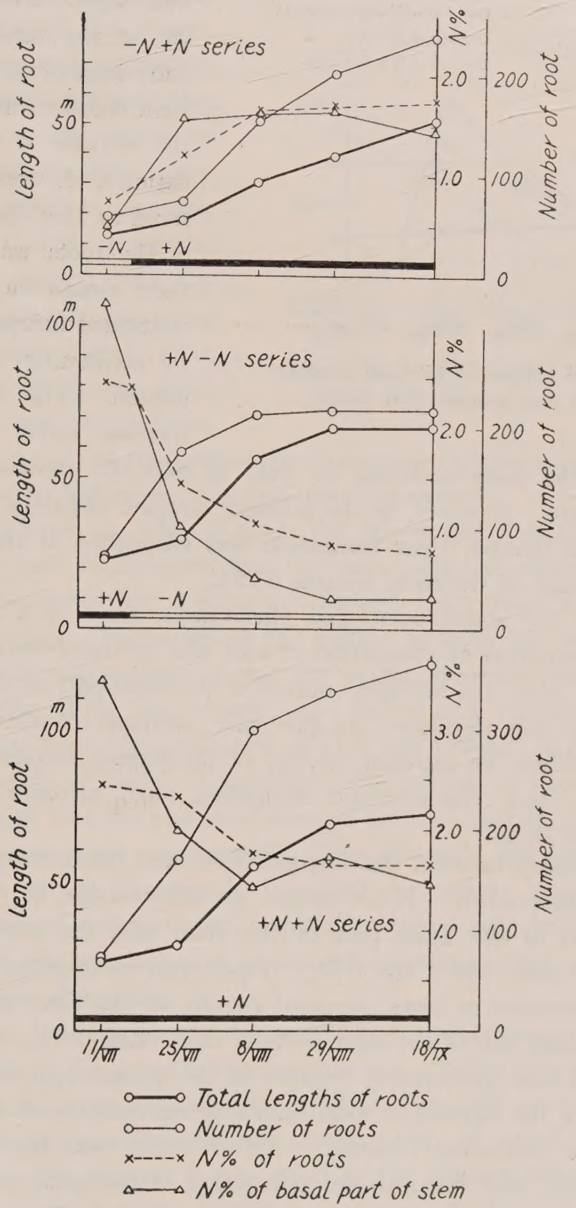

Fig. 2. Length and number of root, and nitrogen content of root and basal part of stem in the experiment series.

increase of root should be stopped at the time when nitrogen percentage of the basal part of the stem less than 1%, although the formation of new roots was remarkable for a time being after the lack of nitrogen. Moreover, as shown in Fig. 3, the increased amount of nitrogen uptake of the root from the basal part of the stem

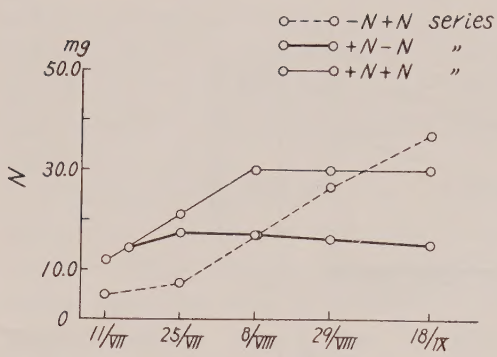

Fig. 3. Total amount of nitrogen content in the experiment root systems (per plant).

was suspended (on and after July 25) at the time when nitrogen percentage of the basal part of the stem became less than 1%, where the increase of total nitrogen of the root showed no longer. Arrived at this stage, development of the roots was dominated by their elongation, as if the roots continued independent elongation by consuming nitrogen in possession. The inversion of the increase ratios of numbers and total length of the roots bordering on July 25 tells the above-mentioned conditions in the figure. However, as the nitrogen amount utilizable for a elongation of the roots was limited, their elongation was suspended at the time when the nitrogen percentage of the roots became 0.75%.

Considering the above mentioned phenomena, there is a uniform relationship between formation or elongation of root and nitrogen content of the plant body. Namely, when the nitrogen content of the basal part of the stem is 1% or more, new roots may develope. In this case, nitrogen content of root itself is about 1.5%. When the nitrogen content of the former becomes 1.0% and less, roots begin to show characteristic elongation until nitrogen content of root become about 0.75%.

The relationship between this nitrogen level and the development of the root was similarly observed in −N+N series. In other words, in −N+N series the nitrogen content of the basal part of the stem and the root at the nitrogen deficient period were 0.50% and 0.75% respectively to stop the formation of new roots, but the number of roots increased rapidly at the time when the nitrogen content of the basal part of the stem, became more than 1.0%, after the supply of nitrogen. After then, presumably because of the nitrogen percentage of the basal part of the stem, the increase of roots numbers was maintained and the elongation of roots became somewhat retarded. +N+N series was the intermediate type between the two, and the nitrogen percentage of the basal part of the stem was always more than 1.5%, which functioned chiefly for the increase of root number.

The growth of the root system refrained from the supply of nitrogen was qualitatively different from that of the root system which actively assimilated nitrogen from the culture solution. In addition, the difference between the two types can be seen from the changes of their unit weight. As shown in Fig. 4, +N+N was increased in accordance with the abvancement of growth and decreased again after the heading stage which had its peak. This phenomenon

can be understood figuratively from the functions of the stem[8]. Namely, it may be said as a successively process of root functions that the root system, at the vegetative growth, which nitrogen metabolism gain dominant position, increase the dry weight and accelerate the degree of elongation with the advancement of growth, but when the root functions decay after heading stage at which the main activity of individual plants turne to the ears[1] and a part of the components contained in roots move into the tops, dry weight of the root decrease with the maturing process.

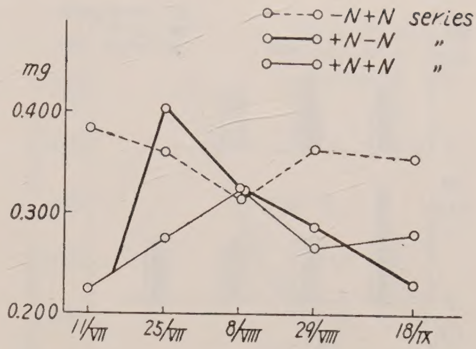

Fig. 4. Dry weight of roots per unit length (mg/cm).

On the other hand, in +N−N series the dry weight of roots was augmented rapidly after the lack in nitrogen, but the value began to decrease in company with a remarkable elongation of roots and became lower than in +N+N series at the maturing stage. Reduction of the culture solution had begun already at the time of the temporal increase of this dry weight, then decreased again by the following supression of the dry weight, and introduced remarkable generation of H_2S. After that time, the generation of H_2S was reduced in proportion to the fall of the dry weight of roots. Accordingly, the increase or decrease of the dry weight in this series took the promoted form of the root system in +N+N series, but their charactors were considerably different with one another. As the decreasing degree of the temporarily increased dry weight was relativley conspicuous, the nitrogen-deficient roots may be considered even from the generation of H_2S to suggest the exudation of some substances into the culture solutions during their unique elongation.

Although in −N+N series the dry weight of the roots came to increase again at the latter stage of the growth, this increase was attributable to B_1 type roots as shown in Fig. 5, being considerably different from the temporal increase of dry weight in the nitrogen deficient root system (+N−N) which was attributable to B type roots. In general B type roots in the nitrogen-deficient series were most dominant among various root types and were the ones which showed the above-mentioned abnormal elongation in the form of a thick size and long lateral roots in a small number, suggesting a close relationship with the reduction of the culture solution. On the contrary, B_1 type roots which were high in nitrogen percentage and comparatively short roots had been most dominant among the root system at the begining of development. In consequence, the increase of dry weight of B_1 type roots in −N+N series after the heading stage may signify

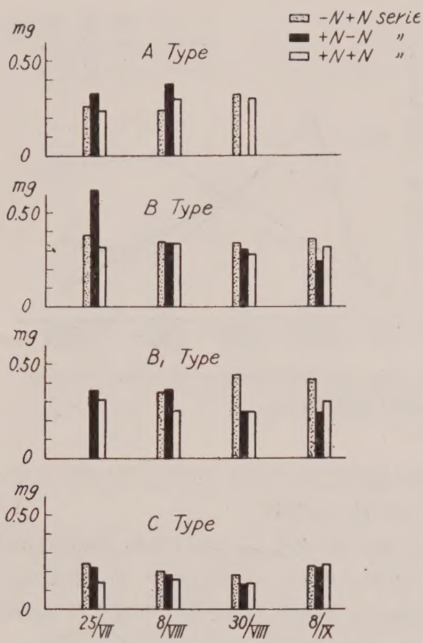

Fig. 5. Dry weight of roots per unit length in each type root (mg/cm).

the reactivation of root functions differently from the nitrogen-deficient series. In other words, as seen in the generation of tillers at the latter stage of the growth, the active vegetative growth even after the heading stage in —N+N series may be related to the reactivation of root functions after the heading stage. As mentioned already on the yield of rice plants, the lowest yield of rice in this series may be regarded as the results of abnormal development in the form of disunity of development of each organ in individual plant and it is noteworthy that under such conditions the rhizosphere was oxidized to exhibit non-outbreak of H_2S. In addition, when the author cut off the ears in +N+N series after the heading stage as demonstrated by Murayama et al[9], the dry weight of roots and the uptake of nutrition increased to surpass those in —N+N series.[note 3] This finding may be regarded as the proof for assuming the increase of dry weight of the roots at the latter stage of growth in —N+N series as the above-mentioned phenomenon.

3. H_2S, esculin oxidation and nitrate reduction by the roots

H_2S, esculin oxidation and nitrate reduction by the roots in an example were illustrated in Table 3 and Figs. 6 and 7. As the oxidation of H_2S by the roots was great in individual difference and moreover H_2S oxidation depended greatly upon iron compounds precipitated on the root surface and other conditions, it was difficult to observe the distinct tendency. However, it was generally seen that the oxidation of H_2S by the roots in +N+N series was the greatest and —N+N series came to the second, and +N—N series tended to be small. Nevertheless, as regards the oxidation of esculin (although it can not be regarded in the same light as the oxidetion of H_2S), this relationship was evidant. In particular, +N—N and —N+N series showed clearly the variation of the oxidation amount in accordance with the presence of nitrogen in the culture solution, and oxidation power of the nitrogen-deficient roots were small. The oxidation amount of esculin per unit weight of roots in —N+N series was higher at the latter stage

Note 3: Not published.

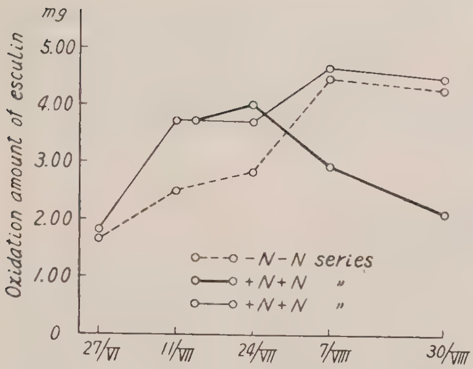

Fig. 6. Oxidation amount of esculin by the root (per plant, after 24 hours).

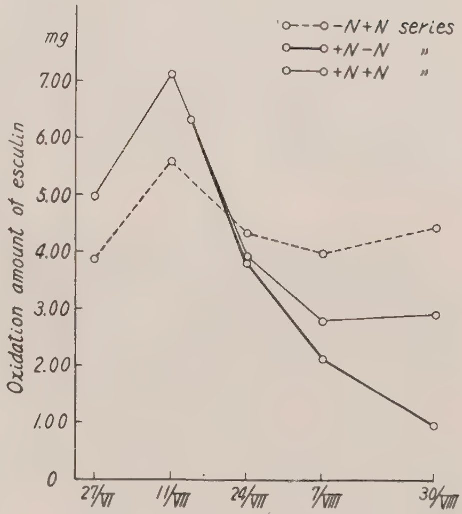

Fig. 7. Esculin oxidation power, of root (Esculin oxidation amount per g of dry weight of root, after 24 hours).

of growth than +N+N series, and moreover the amount which approximated the oxidation amount at the begining of growth would give some evidence to the reactivation of root function in the above-mentioned hypothesis on the dry weight of roots.

The reduction of nitrate by the roots was in the entirely reverse relationship to the aforementioned oxidation. Namely, Nitrite nitrogen was not detected in +N+N series, while in —N+N series, nitrite nitrogen formation

Table 3. H_2S oxidation and nitrate reduction by the roots (21°C dark room).

series	pot No.	12/VII			25/VII			7/VIII		
		after 6 hr	after 24 hour		after 6 hour	after 24 hour		after 6 hour	after 24 hour	
		* ppm sulfide-s	ppm sulfide-s	** r NO_2-N	ppm sulfide-s	ppm sulfide-s	r NO_2-N	ppm sulfide-s	ppm sulfide-s	r NO_2-N
+N+N	1	2.23	1.20	—	2.05	0.16	—	1.86	—	—
	2	2.73	1.60	—	2.40	0.32	—	2.27	—	—
	3			—	2.30	0.32	—	2.13	—	—
	4			—	2.15	0.15	—	2.00	—	—
+N−N	1				2.40	0.76	58.1	4.60	1.18	475.0
	2				2.20	0.50	46.5	4.72	0.40	110.5
	3				2.73	0.90	50.5	4.10	0.80	700.0
	4				2.53	1.02	52.0	4.10	0.82	520.0
−N+N	1	4.07	2.82	89.1	2.00	0.20	149.0	4.23	0.32	—
	2	4.00	2.96	73.1	2.25	0.30	56.5	3.33	0.40	—
	3			90.5	1.95	0.56	120.5	4.60	0.40	—
	4			62.2	2.25	0.20	90.5	4.10	0.35	—
Non-planted		7.00	6.10	—	4.30	1.90	—	7.20	3.16	—

* S′′ in the test solution.

** NO_2-N formation amount per 500 cc test solution.

occurred during the period of nitrogen removing from the culture solution and disappeared gradually after the supply of nitrogen. On the other hand, in +N−N series the formation of nitrite nitrogen became remarkable with the lapse of the time after the removing of nitrogen, being the reverse relationship to the oxidation power.

IV. Discussion

The phenomenon, which indicated the possibility of a close relationship between the reduction of the rhizosphere and the nitrogen nutrition of the rice plants, was the experimental results of Fig. 1, that is, the suspension of nitrogen supply brought about the generation of hydrogen sulfide irrespecitve of any stages of development. However, a problem which arises for elucidation of this problem would be the use of NH_4NO_3, as the sourse of nitrogen. It was used inevitably in order to lessen the variation of pH of the culture solution, but Eh converting from nitrate to nitrite nitrogen was by far greater than Eh reducing sulfate-S into hydrogen sulfide[5]. Accordingly, it is probable that the presence of nitrate nitrogen would not lower Eh until the outbreak of hydrogen sulfide even though rice plants in the nitrogen dosage series participated in the reduction of the medium. Even considering this respect that reduction power of nitrogen deficient roots was strong and its oxidation power was weak under a given condition would mean the reduction of the medium in Fig. 1 owed a great deal to the variation of physiological function as a problem of the roots themselves, that is one of the reaction of rice plant growth in response to the deficiency of nitrogen. If the presence of nitrate nitrogen disturbes the generation of H_2S in the medium, the generation of H_2S was to be seen in a short time after the removal of nitrogen or the removal of NH_4NO_3. In fact, in the cases of Fig. 1 and the removal of nitrogen by means of more detail division of each growth stage of rice plants, the generation of hydrogen sulfide took more than 5 days after the suspension of nitrogen supply and more than 10 days for those with high nitrogen percentage at the time of the lack in nitrogen.[note 4)] Moreover, the variation of the root system being remarkable during that period, the reaction of the root system to the deficiency of nitrogen may be regarded as an important factor for reduction of the culture solution.

When in another experiment the nitrogen-deficient roots and the complete roots (nitrogen-dosage roots) were fixed in the gelatine culture medium (Bouillon culture medium) at 30°C overnight, iron sulfide precipitated on the surface of the nitrogen deficient roots became remarkable as shown in the photo. However, some quantity of iron sulfide was observed only in the nitrogen-dosage roots which were inlaid in gelatine after the removal of the tops, but none of iron sulfide was

Note 4. Unpublished.

detected in the case of the intact roots. These findings may support the above-mentioned discussion.

The mechanism on the reduction of the medium by the nitrogen deficient roots may be unknown and a problem in future. However, the thing which is conceivable easily on the basis of the results in this paper should be supply of energetic substances to the culture medium as being speculated by Mitsui et al[5], which tends to be accelerated by the deficiency of nitrogen. For that reason, a remarkable decrease of the dry weight following its temporal increase was seen during the process of the unique elongation of the nitrogen deficient roots. Consequently, it is possible that a part of substances would be released into the culture medium during the elongation process of roots in addition to the outflow of their components into other organs with the superannuation of the roots. It may be held that reduction of the culture medium would be accelerated particularly in the nitrogen-deficient roots, as the change of physiological functions such as the fall of oxidation power and the rise of reduction power made the

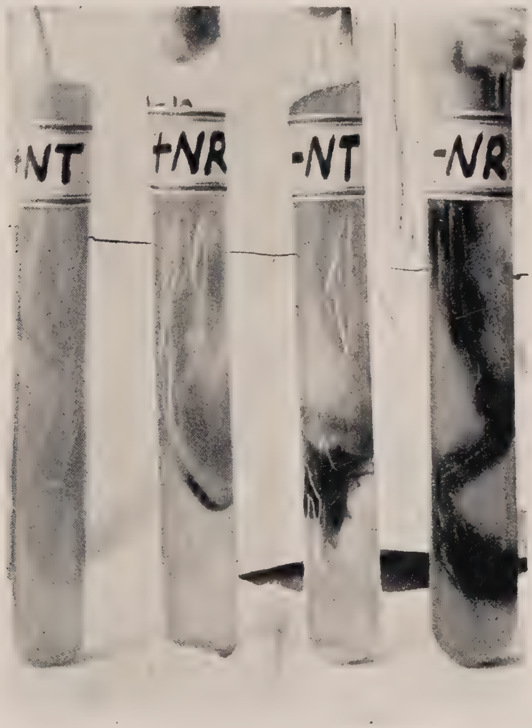

Photo. FeS formation in the rhizosphere of nitrogen deficient roots.

left 2 tube : complete root
right 2 tube : Nitrogen deficient root
T : Intact root
R : Excised root

rhizosphere more suitable environment for growth of microbes in addition to the condition of the former. In practice, in view of the presence of a large quantity of bacillus in the testing solution for reduction power, the participation of the microbes in some stages of the reducing process can be conjectured without difficulty.

Moreover, as reduction of the medium by the nitrogen-deficient roots was a phenomenon in the water culture, this should not be extended directly to the problem of paddy field. However, as Takagi[11] demonstrated rotten roots due to the deficiency of nitrogen ir his experiment of the culture medium containing no organic matters, the problem on the nitrogen nutrition and the reduction of the rhizosphere and the culture medium may be considered to be an universal phenomenon. In particular, rotten conditions of roots in the sandy or paddy fields in the warm district may be attributed to the deficiency of nitrogen in view of the relationship between nitrogen content of rice plants and locality in the paper of Ishizuka and Tanaka[7], in which nitrogen content of the rice grown in the warm district is smaller than that of the plant in the cool district.

V. Summary

The author made comparative studies on the conditions of roots in rice plants which were raised by three different methods of nitrogen supply and their physiological functions. As the results, it was observed that the culture medium lacking in nitrogen underwent remarkable reduction to show the generation of hydrogen sulfide, but the culture medium of rice plants under sufficient supply of nitrogen demonstrated no generation of hydrogen sulfide and was comparatively oxidative conditions.

These phenomena appeared to be the resulti of the variation of root conditions and physiological functions in conformity with the nutritional condition of nitrogen. In other words, the roots lacking in nitrogen indicated an unique development, presenting strong nitrate reduction and weak oxidation of hydrogen sulfide and esculin. From these findings, this paper referred to the relationship between the nitrogen nutrition of rice plants and the reduction of the medium, and the reduction of the rhizosphere or rotten conditions of roots in connection with the growth stages of rice plants, emphasizing the problem of conditions of nitrogen nutrition in rice plant itself.

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Studies on the *Helminthosporium* Leaf Blight of Rice Plant

Part 2. Histological observations on the inner epidermal tissues of leaf-sheaths inoculated with the blight fungus.

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and Teruko ŌMATSUZAWA

(Received on January 20, 1959)

Contents

I. Introduction

Since the earlier reports on histological studies of the blighted leaves of rice plants by Tullis[14] (1935) and of the infection process of the pathogen into the host tissue by Yoshii[15] (1939), several works have been done with regard to similar investigations. Ono[6] made a detailed histological investigation on the blight lesions and suggested a possible relation between the pathological picture of the lesion and the susceptibility of the host plant. Goto[3] also made similar observations with leaf-sheaths inoculated artificially and distinguished four types of pathological pictures. Misawa[5], and Tatsuyama and Yamamoto[13] attempted the histochemical detection of the infected tissues. Tullis[14] stated that in resistant varieties of rice the invading fungus was hemmed in by the formation of deposits, which accumulated in the intercellular spaces about an infection; but Yoshii [17] failed to find such phenomena.

Mizukami[4], from his results of inoculation experiments with the normal and the ether-treated rice seedlings, suggested that an aggressive invasion by fungal hyphae into adjacent host-cells might be a prerequisite for the development of le-

The 184th report of the Institute for Agricultural Research Tohoku University.

sion. Several workers suggested[1,2,16,17] that certain toxic substance or substances might be responsible for the development of lesion, since the initiation of pathological changes in neighboring host-cells preceded to the direct fungal invasion. However, its chemical nature and the mode of its action remained still to be proved.

It was shown in the previous paper that in the muck paddy field the occurrence of the leaf-blight [*Cochliobolus miyabeanus* (*Helminthosporium oryzae*)] increased gradually with the advancing stages of the development of the rice plant, and that of the leaf blast (*Piricularia oryzae*) was rather severe at earlier stages, being followed by an abrupt decline especially after heading. In view of the characteristics in appearance of the lesions and the pathological changes of the affected tissues, the blight lesions could be distinguished into four types: A,B,C, and D. The first type was minute and produced no conidiospores, and the last type was large and produced them consistently. Types B and C formed them with senescence of leaf tissues. Thus, in the field the types of lesions seemed to be much concerned with dispersal of the leaf blight because of their distinct abilities to produce conidiospores.

However, it remained to clarify from what grounds the distinct behaviors of the respective types of lesions might be derived and moreover the cause of the different types of lesions. Prior to further investigation of the problems it would be prerequisite to specify the processes of pathological changes of the infected host-tissues leading to the establishment of the respective types of lesions.

Since a lesion is the pathological expression of the host tissue resulting from interaction between the host tissue and the invading pathogen, the different types of lesions may imply corresponding different reactions between them. It is necessary to investigate, therefore, by what factor or factors the occurrence of a given type of lesion may be conditioned and through what process of the pathological change such type of lesion may be established. The present work was undertaken to clarify the first problem for the leaf blight. Some comparative observations were also made with the leaf blast.

Inoculation experiments were carried out exclusively by means of the sheath inoculation technique[7,10]. It might be advantageous to follow successively the process of pathological change developing in a living tissue under the microscope. It should be kept in mind, however, that a leaf sheath may be somewhat dissimilar to a leaf blade in certain respects as pointed out elsewhere[7,9]. Procedure of inoculation, including the preparation of inoculum, and of the observation were described in the previous paper. Inoculated materials were immediately examined under the microscope or preserved in 20 percent alcohol solution before observation.

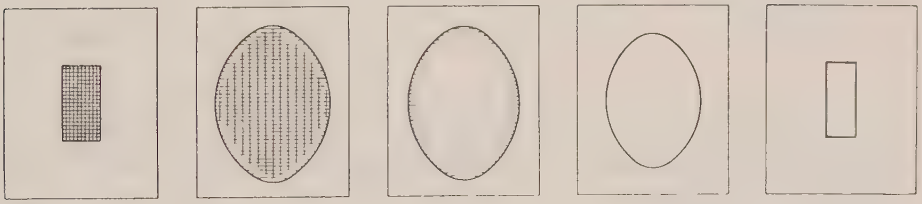
The authors express their appreciation to the members of the research group of the Institute engaged in the "Studies on muck paddy fields" for their kind assistance and for many helpful suggestions.

II. General features of the pathological pictures induced by the blight fungus

It may be convenient to outline the pathological pictures of the blight-infected tissues of leaf sheaths. From the results of the observations carried out in 1956 and 1957, the following five types of lesions were distinguished (Fig. 1). Observations under the microscope were made on stripped epidermal tissues within 48 hours after inoculation.

Type I : A minute lesion consisting of few, deep brown cells; the degree of invasion* is low, mostly from 0.5 to 1.0 (Pl. II : 1, 10). Hyphal development in the penetrated host-cell is hardly visible. Irregular, fine granules of light yellow or brown color fill evenly the epidermal cell immediately under the appressorium and its neighboring cells, or aggregate densely at their peripheries. Thus the affected cells can be distinguished from the healthy ones.

Type II : Number of the affected cells are more numerous than that of the former type, reaching occasionally up to 150 cells, but their browning is less conspicuous. Invaded hypha grows well. Colored granules in the infected cells are generally larger than those in the former and distribute sparsely around the part, on which the appressorium settles. The more the cells are apart from the penetrated cell, the less they may granulize and discolor (Pl. I : 3–4).



Type I *Type* II *Type* III *Type* IV *Type* V

Fig. 1. Schematic representation of various types of lesions appearing in the blighted inner epidermal tissues of leaf sheaths. Hatching indicates browning of the affected-tissue, and white part the pale or no coloration.

Type III : Size of the affected area is as large as that of type II. Invaded hypha develops well. Both discoloration and granulation in the penetrated cell and its neighboring cells are less intensive, but rather conspicuous in the peripheral cells not yet exposed to direct attack by the fungal hyphae.

Type IV : Number of the affected cells somewhat less than that of type II

* (10, p. 63) $S=\Sigma\, df/n$; n : total number of the appressoria formed on the inner epidermal cells of leaf-sheath and produced infection hyphae; d : numerical value given to each appressorium according to the estimation of growth of the hypha produced from it; f : frequency of the occurrence of appressoria having respective d value.

or III. The penetrated cell discolors a little or does not, but the neighboring cells may produce pale yellow or almost hyaline, crystal-like granules. Distinction between the affected and the healthy cells is more or less obscure (Pl. II : 6).

Type V : Number of the affected cells is much limited as in type I ; but hyphal development and discoloration in the penetrated cell are hardly observable. Protoplasmic aggregation, or arborescent or radial formation of hyaline granules may be seen (Pl. II : 8). This type of pathological picture is similar to that described by Takahashi[11] in his studies on the blast-infected tissues of leaf-sheaths.

Characteristic features of the above mentioned types of lesions are shown in Table 1.

Table 1. Showing the characteristics of various types of the blight lesions on inner epidermal tissue of sheath.

Type of lesion	Penetration by the fungus	Hyphal development in the invaded host-cell	Discoloration in the invaded host-cell	Discoloration of host cells, not yet exposed by the fungal attack	Distinction between the affected and the healthy part	Size of lesion (No. of affected cells)	Type of lesion after Goto[3]
I	Hardly observable	+	++～+++	++～+++	Clear	Minute (1-10)	D
II	Definitely observed	++	++	++	Obscure	Large (>25)	B
III	〃	++	−	+～++	Somewhat clear	Largest (>45)	A
IV	〃	+～++	±	±	Obscure	Large (>20)	C
V	Hardly observable	±	±	−	Obscure	Minute (1-5)	

As shown in Table 1, the size of lesion seemed to depend upon the active development of the fungual hyphae within the affected tissue. Thus such types producing large lesion as II, III, and IV, showed good hyphal development. In such types forming minute lesions as I and V, the hyphal development was hardly observed in the penetrated host-cell.

Pathological pictures induced by the blast fungus were divided into the following four types :

Type i : The invading hypha develops well within the infected area. Discoloration is not so conspicuous as in type ii, but the invaded cells contain often blackish brown, large granules (Pl. I : A, B). This type was always found on susceptible hosts.

Type ii : The penetration hypha usually develops a little; but the invaded cells show blackish brown necrosis (Pl. I : C). This type was found often in the tissues of the older plant, even of a susceptible host.

Type iii : Development of the invaded hypha is limited exclusively to the infected cell by the penetration hypha; and a few necrotic cells are found usually around the infected cell. They contain mostly light brown or brown, sandlike

granules (Pl. I : D-E). This type was observed always on very resistant hosts.

Type iv : The pathological picture of this type resembles closely that of type V produced by the blight fungus (Pl. I : F-H). It was observed usually in the older tissues of both resistant and susceptible hosts. Takahashi [11] noted this type in his studies on the pathological pictures by the blast fungus.

III. Results of the observations

1. Pathological changes in the tissues from leaves of different positions on a haulum : observations from 1955 to 1956.

Materials and methods : Plants to be tested (Norin No. 16 variety) were grown in Wagner's pots (16.5 cm in diameter and 18.5 cm in depth), filled with 2.5 kg of ordinary paddy soil. Three gramms of ammonium sulfate, 3.1 g of calcium superphosphate and 1.0 g of potassium chloride per pot were given. One plant was grown in each pot.

Seeds were sown on Sept. 1, 1955. After ten days in a greenhouse, the potted plants were transferred into Phytotron (an experimental chamber capable of regulating of both temperature and moisture conditions under artificial illumination).

Observations were made on Jan. 25 and Feb. 13 in 1956. In both cases the inner epidermal tissues of sheaths taken from the leaves of different positions on a main haulum were inoculated with the blight fungus. Preparation of inoculum, and procedures for inoculation and microscopical observation were described elsewhere[8]. The results obtained are listed in Table 2.

Table 2. Results of the inoculation experiments with the blight and the blast fungi.

Date of inoculation	Position of sheath, inoculated	Blight fungus			Blast fungus		
		No. of appressoria, observed	Percentage of appres., penetrated (%)	Degree of invasion	No. of appressoria, observed	Percentage of appres., penetrated (%)	Degree of invasion
Jap. 25, 1956	The 1st (10/0)	146	62.9	1.86	197	94.7	6.70
	The 2nd (9/0)	98	88.2	4.66	183	92.0	8.21
	The 3rd (8/0)	118	85.5	6.58	210	80.4	4.50
	The 4th (7/0)	107	78.7	5.41	316	76.8	3.28
Feb. 13, 1956	The 1st (10/0)	140	67.5	2.20	165	91.4	7.50
	The 2nd (9/0)	113	87.8	5.32	206	89.6	10.11
	The 3rd (8/0)	162	90.0	7.40	197	78.2	4.00
	The 4th (7/0)	102	74.8	6.67	213	60.0	3.15

The first leaf, as it was called in this paper, denoted the uppermost one on a main haulum at a given day. Thus, as the average numbers of leaves on Jan. 25 and Feb. 13 were 9.8 and 12.0, respectively, the first leaves at the respective dates might be of the tenth (10/0) and the twelfth (12/0) positions on the main haulum.

Shift of the invasion degree from the upper leaf-sheath to the lower differed between the blight and the blast. With the former it tended to increase from the sheath of the uppermost leaf to that of the lower one, while with the latter it showed a reversal tendency. The invasion degrees for the sheaths from the same position, for example the nineth, in each inoculation were 4.66 and 6.67 with the blight, and 8.21 and 3.15 with the blast, respectively. Thus it could be said that younger tissues might be more resistant to the blight infection than the older or senescent ones; whereas to the blast infection, a reverse might be the case.

Hyphal developments of both pathogens within the lesions were examined under the microscope. All the lesions observed were divided into 5 groups, as shown in the first column of Table 3, according to the number of the invaded host-cells counted in each lesion. 0 means the lesion, in which hyphal growth can be hardly seen microscopically in the penetrated and discolored host cell. Figures in Table 3 represent the percentage of the frequent occurrence of each group to total infections secured in respective sheath.

Table 3. Percentage of the lesions belonging to each group to the total lesions appearing on the sheaths of different leaf-positions (Inoculation experiment on Jan. 25, 1956).

Number of the affected cells in a lesion	Blight fungus				Blast fungus			
	10/0	9/0	8/0	7/0	10/0	9/0	8/0	7/0
0	27.1	11.8	14.6	21.3	5.3	7.9	18.6	23.3
1—2	58.5	68.6	59.2	60.3	45.2	37.0	66.0	67.0
3—5	4.4	16.6	26.3	18.4	38.4	44.0	15.3	9.7
6—10		3.0			11.2	8.8		
>10						2.4		

From Tables 2 and 3, it seemed with both pathogens that the degree of invasion might show a higher value when many invaded cells were found in a lesion. Difference in the invasion degree of the blight fungus on the 10/0 and the 9/0 sheaths, however, seemed to be dependent rather upon the hyphal density in an invaded cell than upon the number of invaded cells in a lesion. In general, the number of the invaded cells by the blight fungus was less than that by the blast. However, the pathological changes in the host-cells, such as discoloration or granulation, by the blight fungus extended even to the cells not yet exposed directly to the hyphal ottack. With the blast this was not the case.

It may be seen that one conidiospore of the blight fungus geminates usually through one or more germ tubes and forms appressoria at respective ends. Consequently infection may be often secured through almost simultaneous penetration by several appressoria from one and the same conidiospore. Table 4 shows that the blight lesion resulted from several penetrations covered more affected cells than that from a single penetration.

Table 4. Showing the number of appressoria attached on one lesion and of the affected cells consisting of a lesion.

Leaf position		10/0	9/0	8/0	7/0
Number of the appressoria attached on one lesion	1	17.4*	30.5	42.3	?**
	2	44.3	84.2	?	?
Discoloration		+++	++	+～+++	±

* Average number of the affected cells consisting of one lesion.
** Distinction between the affected and the healthy cells was obscure.

Number of the affected cells per a lesion increased considerably towards the lower sheath. And from Tables 3 and 4, it could be clearly seen that number of the affected cells was far greater than that of the invaded cells directly by the pathogen.

Although various types of lesions might appear usually on the same sheath as well as on the same leaf blade, the rate of appearance of each type seemed to be characteristic to each sheath from different leaf-positions (Fig. 2.)

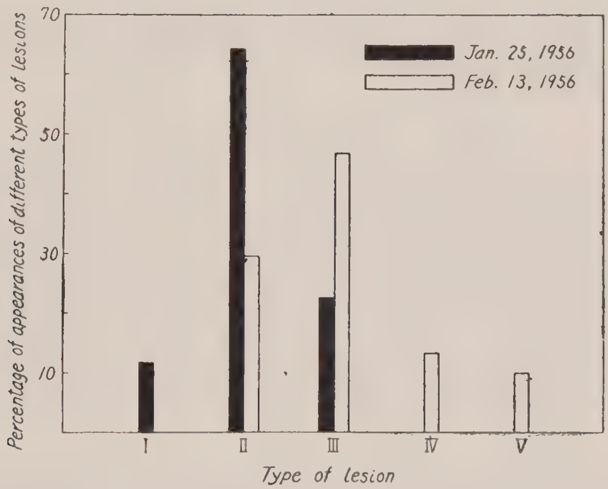


Figure 2. Percentage appearance of the lesions belonging to each type to the total lesions on the sheaths from different leaf-positions (Inoculation on Jan. 25, 1956).

As shown in Figure 2, type I was predominant on the 10/0 sheath, type II on the 9/0, types II and III on the 8/0, and type I on the 7/0, respectively. But it was remarkable that almost all the lesions belonging to type III on the 10/0 sheath were penetrated through two or more appressoria. Type V could not be found on the 10/0 and the 9/0 sheaths, and type I did not on the 7/0. It seemed also that the types of lesions might shift from I to IV or V with the aging of leaves as clearly shown in Fig. 3.

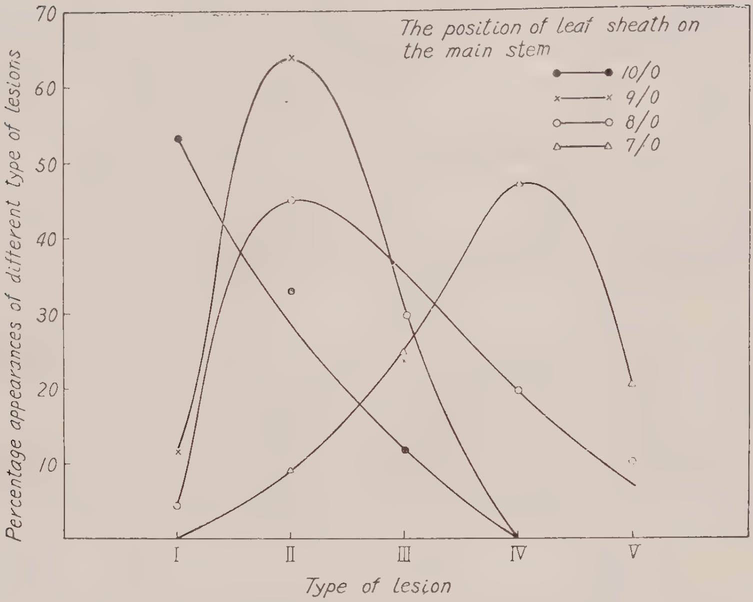


Fig. 3. Percentage appearances of different types of lesions on the sheaths from the different leaf-position on Jan. 25.

2. Effect of different supplies of nitrogenous fertilizer upon the pathological changes of tissues: observations in 1957.

One seedling in each pot (Norin No. 16 variety) was transplanted on June 10. Every pot contained 2.5 kg of muck paddy soil and was supplied with the fertilizers as already described (control plant). And on June 18, 0.5 g of ammonium sulfate per pot was further added to some of them (additional nitrogen plant).

On July 31, sheaths from the 12/0, 10/0, and 8/0 leaves were inoculated with both pathogens, respectively. Conidia produced newly on the blasted leaves of

Table 5. Results of the inoculation experiments on

	Leaf position	Blight fungus			
		No. of appressoria, observed	Percentage* infection (%)	No. of invaded** cells (aver.)	Invasion degree
Control plant	12/0	147	70.3	1.3	2.60
	10/0	194	83.6	1.6	4.14
	8/0	106	39.8	1.2	1.87
Additional N plant	12/0	136	54.5	1.1	1.59
	10/0	218	94.7	2.0	5.34
	8/0	172	88.0	2.3	6.07

* Percentage of appressoria, penetrated into a host cell, to the total appres-

** Observed on the penetrated appressoria only.

Moko-ine (susceptible variety) under moist conditions were used as inoculum. Results are given in Table 5.

The blast fungus: Both the degree of invasion and the percentage infection were greater in higher leaf-sheaths than those in lowoer ones regardless of different nitrogen supplies. Number of the invaded cells consisting of a lesion increased also in the higher ones. In view of the leaf position, the degree of invasion, the percentage infection, and the number of the invaded cells per lesion were higher in additional N plants. The pathological change of host cell showing a hyaline or pale yellowish granulation (Pl. I: G H), as noted by Takahasahi[11], was recognized more frequently in control plants (somewhat nitrogen deficient) and also in lower sheaths.

The blight fungus: In general the degrees of invasion were higher in additional N plant excluding that of the 12/0 sheath. And, in respect to the leaf position, they showed again a reverse tendency to those of the blast in additional N plants, and were 10/0, 12/0, and 8/0 in decreasing order in control plants.

Types IV and V appeared more frequently on sheaths from control plants, and II and III on those from additional N plants. Hyaline granulation (V) occurred often in sheaths from control plants.

3. Transition of the pathological pictures through the development of host plant: observations in 1955.

Rice plants under test were grown in the muck paddy field at Yamotomachi, Miyagi Prefecture. Detailed description of their culture and of the climatic conditions during their growth were given in the previous paper [8]. A part of the results, viz., the drift of invasion degree through the growing period, was also presented in that articls. Accordingly the drift of pathological picture or type of lesion will be given in this section.

Norin Nos. 16 and 21 and Moko-ine varieties were examined. Since variations in the pathological picture of each variety followed approximately the

the sheaths from plants with different N supplies.

	Blast fungus				
Type of lesion	No. of appressoria, observed	Percentage* infection (%)	No. of invaded cells** (aver.)	Invasion degree	Type of lesion
II, III(IV)	234	89.5	3.0	7.43	i, ii
III. IV	228	77.7	1.5	2.26	ii
IV(V)	256	46.8	1.0	1.00	iv(ii)
I, II	263	98.4	4.2	10.30	i
II(III)	325	87.6	1.9	3.67	i, ii
II, III	255	75.6	1.0	1.54	ii' iv

soria attached to epidermal surface.

similar drift, the results of observation only with Norin No. 16 variety will be mentioned here (Table 6).

Table 6. Results of the inoculation with the blight fungus on leaf-sheaths from the plants in various growth stages (Norin No. 16 variety, 1955).

Date of inoculation	July 18	21	72	August 2	9	18	31	Sept. 2
Control plant								
No. of appressoria, observed	86	93	106	67	124	138	97	69
Percentage infection (%)	75.0	63.6	85.7	86.7	89.0	88.4	70.2	81.0
Degree of invasion	3.76	2.28	3.34	4.40	6.83	5.03	2.83	4.20
Type of lesion	II*(III)**	〃	〃	II, III	〃	〃	III, IV	〃
Additional N plant								
No. of appressoria, observed	72	63	122	89	117	135	106	75
Percentage infection (%)	78.2	59.8	88.6	89.0	92.3	89.5	78.1	86.6
Degree of invasion	2.93	1.88	2.90	4.20	5.13	6.92	3.70	3.82
Type of lesion	II(I, III)	〃	II(III)	〃	〃	〃	II, III	III, II

* Predominant type ** Additional type.

Drift of the type did not show a clear-cut trend as in the foregoing inoculation experiment (Sec. 1). Under field conditions the sheaths to be inoculated could not be taken invariably from the leaves of definite position in each sampling. So it should be satisfied with the general aspect for the transition of pathological picture through the development of the host plant. From transition of the blight outbreak in the paddy field and drift of the type of lesion appeared on inoculated sheaths, it might be expressed as follows :

Growth stage	Tillering →Head-bearing →Heading
Transition of the disease outbreak	Slight——————→Severe
Drift of the type of lesion	II (III, I) → II, III (IV) →III, IV (V)

During the period from heading to ripening the hyphal development within the invaded cells declined gradually and the discoloration of lesion became faint. The type of lesion shifted correspondingly from II or III to IV or V. Goto[3] also found similar changes of pathological pictures, and Yoshii[17] found that the rate of enlargement of lesion was rather high at the seedling stage, which was followed by a decline at tillering and head bearing stages and by further decline after heading. These findings seemed apparently to coincide with the above observations. In the muck paddy field, however, large lesions such as "gray spot" type (D) (8, p. 134) appeared predominantly after heading. And it may be very difficult, by an artificial inoculation, to induce the formation of such large type of lesion on the plants, that were grown in an ordinary paddy soil.

4. Varietal differences in the pathological pictures.

To examine comparatively the varietal differences of pathological pictures induced by both pathogens, several varieties of rice plant were employed. They are listed in Table 7 together with their characteristics.

Table 7. Showing the characteristics of the varieties of rice plant under test.

Variety*	Ripening	Panicle type	Blast resistance	Remarks
1. Norin No. 1	Early	Many	Very susceptible	Japonica
2. Rikuu-Kamenoo No. 4	Medium	Heavy	〃	〃
3. Nantoyo-Sen	Late	Many	〃	Indica
4. $55F_5$-504	Early	Many (more or less)	Very resistant	Japonica
5. $55F_5$-109	Medium	Heavy	〃	〃
6. Usen	Late	Many	〃	Indica
7. Kannon-Sen	Late	Many	〃	〃
8. Moko-ine	Very early	Many	Very susceptible	Japonica
9. Ishikari-Shiroke	〃	Heavy	Resistant	〃
10. Wase-Fukoku	〃	Heavy	Susceptible	〃
11. Norin No. 16	Medium	Many	Medium resistant	〃

* Varieties (1–6) were received from Tohoku Agr. Exp. Sta.; varieties (9–10) from Hokkaido Agr. Exp. Sta.

Seeds were sown on April 21; and on June 1 12 seedlings were transplanted in a concrete box (50×50×30 cm) filled with muck paddy soil. Twenty three gramms of ammonium sulfate, 12 g of calcium superphosphate and 8 g of potassium chloride were supplied. On July 20* and Aug. 7** five plants of each variety were examined by means of the sheath inoculation method. Freshly produced blast conidia collected from lesions on leaves of Norin No. 16 variety were used as inoculum. Inoculated plants were incubated at 23°–24°C for 30 hours with the blight fungus and 42 hours with the blast. Results are given in Tables 8 and 9.

Results are summarized as follows:

(1) With the exceptions of the blighted Norin No. 1 and Ishikari-Shiroke and the blasted $55F_5$-109, both the percentage infection and the invasion degree decreased with delaying of inoculation time, that is, with advancing stage of plant growth, in every variety. But the rate of decreasing was more remarkable with the blasted plants.

(2) Varietal differences of the invasion degree shown in the first inoculation experiment (July 20) conformed with those of the blast proneness hitherto known, but in the second inoculation (Aug. 7) such varietal differences were lost with the exception of Wase-Fukoku, a very susceptible variety.

Although the invasion degree of each variety by the blight fungus was not always ranked with the same order in both inoculations, such a variety as Kannon-

* The blast was inoculated on the 10/0 sheath; and the blight on the 9/0.

** Ishikari-Shiroke and Wase-Fukoku varieties were inoculated on the sheath of the second leaf from a flag leaf; the others on that of the third leaf.

Table 8. Results of the inoculation with the

Variety	July 20							
	A	B	C	D (%)				
				<10	>10	>30	>50	⋗70
Norin No. 1	129	69.6	2.87	III	II			I
Rikuu-Kamenoo No. 4	146	88.4	3.37	III	II			I
Nantoyo-Sen	112	98.0	10.60		II	III	IV	
$55F_5$-504	170	92.0	6.10	III	I, IV			II
$52F_5$-109	123	74.2	5.C2	III	I			II
Usen	128	92.7	5.56	IV	III, I		II	
Kannon-Sen	170	94.5	7.28		IV, II	III		
Moko-ine	122	98.3	9.55	III		II	IV	
Ishikari-Shiroke	156	52.4	1.08	II		III	I	
Wase-Fukoku	97	86.9	4.26	I, III			II	
Norin No. 16	105	84.7	5.28		III, I		II	

A : Total appressoria observed; B : The percentage of the penetrated appres-
of each type in percentage.

Table 9. Results of the inoculation with the blast fungus on various varieties of rice plant.

Variety	July 20				August 7			
	No. of appres-soria, observ-ed	Percent-age in-fection (%)	Inva-sion degree	Type of lesion	No. of appres-soria, observ-ed	Percent-age in-fection (%)	Inva-sion degree	Type of lesion
Norin No. 1	127	97.0	11.44	i	155	88.0	1.68	ii(iv)
Rikuu-Kamenoo No. 4	180	98.8	8.79	i	240	79.7	0.66	iv
Nantoyo-Sen	214	93.8	11.27	i, ii	123	82.3	0.75	iv
$55F_5$-504	269	89.4	3.56	iii, iv	183	61.3	0.58	iv
$55F_5$-109	252	66.9	1.55	iii	253	80.4	1.40	ii, iv
Usen	216	47.5	1.26	iii	180	15.8	0.61	iv(iii)
Kannon-Sen	148	65.8	1.38	iii	212	29.4	0.63	iv
Moko-ine	185	91.2	12.30	i	—	—	—	
Ishikari-Shiroke	315	70.8	1.51	iii	148	18.6	0.62	iv
Wase-Fukoku	166	97.6	11.09	i	151	84.9	3.46	ii,iv
Norin No. 16	207	95.3	6.02	i	160	75.6	1.38	iv, ii

Sen or Nantoyo-Sen showed invariable higher degree. It was interesting that the varieties belonging to the "Indica type" presented generally higher degree in comparison with those to the "Japonica type".

Based on the results of the first inoculation (July 20), in which varietal differences of the proneness to the blast disease were clearly distinct, all the varieties under test could be divided into the following four groups :

Group a : showing rather high degree of invasion to both pathogens (Nantoyo-Sen, Moko-ine);

Group b : showing low degree to them (Ishikari-Shiroke);

Group c : showing high degree to the blast but low to the blight (Norin No. 1, Rikuu-Kamenoo No. 4);

blight fungus on various varieties of rice plant

August 7							
A	B	C	D (%)				
			<10	>10	>30	>50	>70
88	76.1	3.52	III	I	IV	II	
75	43.0	1.25		III	IV	V	
129	92.5	5.76	V	II	IV	III	
112	82.6	4.23	V	III, IV	II		
160	55.3	1.18		III	IV	V	
98	91.0	4.01	V, II	IV	III		
113	87.8	4.50		IV	III, II		
—	—	—	—	—	—	—	
76	39.8	1.82	II, I	III	IV, V		
63	63.8	2.04	II, I	V	IV, III		
122	87.1	3.64	II	V	III	IV	

soria to the total; C : Degree of invasion; and D : Frequency of appearance

Group d : showing a reverse degree to Group c (Kannon-Sen, Usen, $55F_5$–504).

The fact that there exists a blast-resistant variety showing high degree of invasion to the blight or a blast-susceptible one showing low degree to the blight may permit comparative studies on the mechanisms of the host-parasite reactions between two different pathogens and their common host.

(3) The varieties that gave very low degree of invasion to the blast (very blast-resistant) revealed the pathological picture (Pl. I : C-E), in which the cell content turned to yellowish brown, sandlike granules and the hyphal development was very meager. The varieties that gave high degree to the blast (very blast-susceptible) revealed the pathological picture (Pl. I : A, B), in which the cell content turned to deep brown or blackish brown, irregular, large granules and the hyphal development was good.

(4) The pathological picture which had a wide discolored zone consisting of numerous affected cells around the blight-infected focus, such as type II or III, could not be found in the case of blast infection with the exception of Usen variety in the second inoculation. On the contrary, the pathological picture of blasted tissue, in which the cell content and also the invaded hyphae turned to deep brown but no discoloration of surrounding cells was caused (Pl. I : A,B), could not be found in any blighted tissues. This type may be found frequently in the blasted sheath of the most susceptible variety, such as Norin No. 1 or Moko-ine.

(5) The pathological pictures of types I and V in the blight-infected tissues showed resemblance in that the penetration from an appressorium could be barely observed or not microscopically, in other words, the hyphal development within the penetrated cell was very meager. In the former, however, the penetrated cell turned to pale yellowish brown, while in the latter no discoloration occurred. Pathological picture similar to the former (type I) was found in the sheaths from

blast-resistant varieties, such as Kannon-Sen, Usen and Ishikari-Shiroke, in the first inoculation (Pl. I : D-E). Type V was found exclusively in the sheaths from aged and senescent leaves, even of the blight susceptible variety in the second inoculation. It seemed to be a prevailing type of pathological change particular to an extremely senescent tissue.

IV. Summary

Histological investigation was made on the pathological changes in the inner epidermal tissue of leaf-sheath of the rice plant inoculated with the blight fungus. Comparative observation was also made on those inoculated with the blast fungus.

1. Blight lesions were divided into five types, viz., I, II, III, IV, and V, in view of the differences of hyphal development in the host tissue and of the discoloration and the granulation of cell content due to infection, and size of the affected area.

2. Blast lesions were also divided into four types, viz., i, ii, iii, and iv, according to the above criteria.

3. Percentage appearances of different lesion-types by both pathogens on a leaf-sheath showed the characteristic patterns due to its age and position on a haulum. For example, type I of the blight lesion (resistant type) was exclusively dominant on the elongating uppermost (youngest) leaf-sheath, but it was replaced gradually by types II-IV or V on those of lower positions. Type i of the blast lesion (susceptible type) appeared more frequently on the upper leaf-sheath than on the lower. Thus it could be concluded that younger (higher leaf-position) tissues might be more resistant to the blight infection than older or senescent (lower position) tissues, whereas to the blast infection a reverse might be the case.

4. Invasion degrees by both pathogens in the tissues from additional nitrogen plants were higher than in those from control plants. In view of the leaf-position on the same plant, however, they remained to show the reverse tendencies.

5. Several varieties of rice plant were examined as to their disease proneness to both pathogens by means of the sheath inoculation technique. It was interesting that a blast-resistant variety was not necessarily resistant to the blight.

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Explanation of plates

Pathological changes developed in the inner epidermal tissues of leaf sheaths of rice plant (incubation temperature : about 24°C); s, condiospore; g, germ tube; a, appressorium,; h, fungal hypha.

Plate I (1956) : Pathological changes developed within 40 hours after inoculation with the blast fungus.
①-② : type i, Norin No. 1 variety, inoculated on July 20. ③ : type ii, Norin No. 1, inoculated on Aug. 7. ④ ⑥ : type iii, inoculated on July 20; ④, Ishikari-Shiroke; ⑤, Usen; ⑥, $55F_5$-109. ⑦-⑧ : type iv, inoculated on Aug. 7; ⑦, Kannon-Sen; ⑧, Norin No. 16.

Plate II (1956) : Pathological changes developed within 30 hours after inoculation with the blight fungus.
①-②: type I, Norin No. 1, inoculated on July 20. ③-④: type II, Norin No. 16, inoculated on July 20. ⑤-⑥ : Invaded hyphae and granulation of cell content in the lesion of type II, Norin No. 16, inoculated on July 20. ⑦ : Pathological change and invaded hyphae in the lesion of type IV, Norin No. 1, inoculated on Aug. 7. ⑧ : type V, showing the hyaline granules aggregated around the penetrated appressorium; $55F_5$–109, inoculated on Aug. 7.


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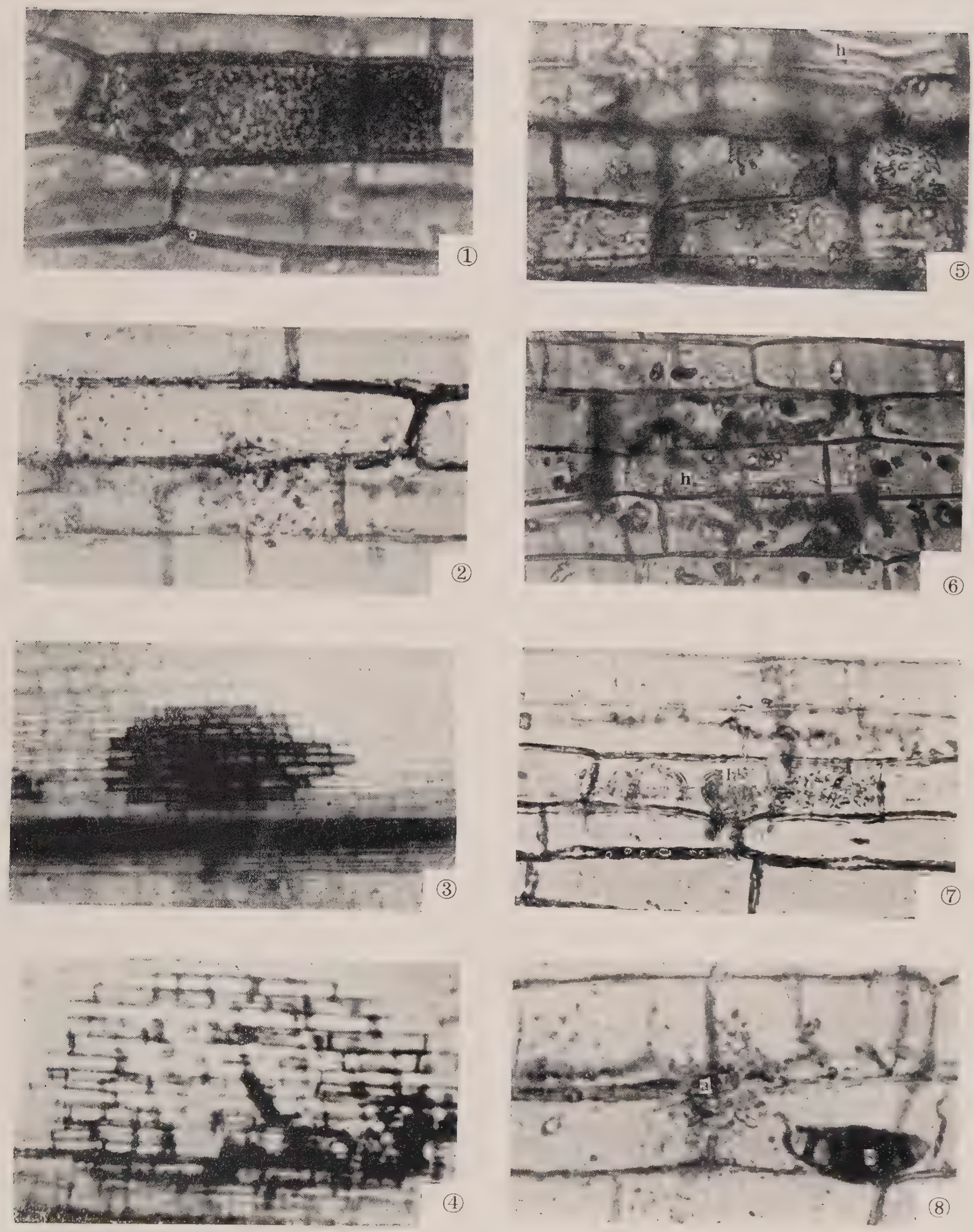
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Studies on the Spacing Density of Rice Plant

Part 2. Interrelationships between the spacing density and the mode of hill arrangement

Mikio KANDA and Yôsei KAKIZAKI
(Received on February 25, 1958)

I. Introduction

In the previous report (1956) the authors investigated the effects of spacing density on growth and yield of rice plants under the limited condition of one-plant-planting per hill in a regular and square hill arrangement. The study based on such the hill arrangement was due to the fact that the plantation mode of square hill arrangement with one plant per hill among various mode of plantations is regarded as the simplest and the original type of planting modes with the exception of irregular planting and semi-regular planting.

From the viewpoint of arrangement mode of seedlings, rectangular hill arrangement, "namikiue" or row-transplanting, "suue" or nest-planting arranging individual seedling at certain regular intervals in the hill and square hill arrangement with different numbers of seedlings per hill can be regarded as a derivative type from the square hill arrangement with a plant per hill. For example, as regards the square hill arrangement with a plant per hill and with multiple plants per hill, these two modes of transplanting can be considered to be the two extremities of a serial transplanting modes as a transitional type of "suue" which transplants seedlings at different individual spacing in the hill. (see Fig. 1)

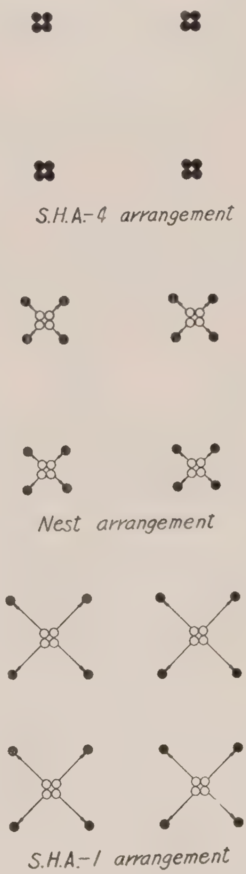

Fig. 1. Schematic description of relationship between planting modes.

The experiment in this paper was conducted at Kashimadai Experimental Farm, Institute for Agricultural Research, Tohoku University in

The 189th report of the Institute for Agricultural Research, Tohoku University.

1956 for the purpose of investigating relationships between the spacing density of seedlings at transplanting and the serial variation of the above-mentioned modes of hill arrangement as well as determining the quantitative variation of growth and yield of rice plants in various modes of hill arrangement.

II. Experimental method

1. Mode of hill arrangement

Among various modes of hill arrangement, this paper made an attempt to investigate the change of a serial modes of hill arrangement ranging from the square hill arrangement with a plant per hill to the square hill arrangement with four-plant-planting per hill through "suue" arrangement mode as shown in Fig. 1. Although the "suue" arrangement mode may be regarded as a typical transitional type which appears in change of mode from the square hill arrangement with one-plant-plantiug per hill to that with four-plant-planting per hill, the square hill arrangement with one-plant-planting per hill and that with four-plant-planting per hill can be, from a different point of view, comprehended as a special case under a broad interpretation of the "suue" hill arrangement. In other words, the square arrangement with one-plant-planting per hill is a "suue" arrangement at an equal distance of individual spacing in the adjoining position, so that the square hill arrangement with four-plant-planting per hill may be regarded as "suue" arrangement which is naught approximately in individual spacing in the hill. Such a way of understanding, concerning the square hill arrangement with one-plant-planting per hill and that with four-plant-planting per hill may be much easier and more convenient for expression. However, it goes without saying that the prescription of spacing density by number of transplanted seedlings per unit acreage is needed for rationalization of such a understanding from the viewpoint of spacing density. In the present paper emphasis will be placed on the above-mentioned respects. Although the modes of hill arrangement subject to the experiment were such as given in Table 1 in relation to the difference of spacing density, sparse planting plots with 4 hills and 9 hills per tsubo were established especially for the square hill arrangement with one-plant-planting per hill.

2. Spacing density

As seen in Table 1, the experiment was made on a wide range of spacing density at seven levels from sparce planting of 16 seedlings per tsubo to dense planting of 1600 seedlings per tsubo with the exception of the square hill arrangement for which plots of 4 hills and 9 hills per tsubo were established additionaly. The spacing density referred here does not mean the so-called number of hills per tsubo but the number of transplanted seedlings as stated in the previous paper. For example, even though the number of seedlings per tsubo were 36 plants, the number of hills per tsubo would be 36 in case of the square hill arrangement with one-plant-planting per hill and 9 in case of that with four-plant-planting per hill.

Table 1. Experimental plots.

		Planting mode (distance between individuals within the hill) 0 3 3.75 5 7.5 10 15
Spacing density (number of seedlings per unit area (1 tsubo)	16	○—△—△—△—△—△—□
	36	○—△—△—△—△—□
	64	○—△—△—△—□
	144	○—△—△—□
	256	○—△—□
	400	○—□
	1600	○

note : □, ○, and △ shows SHA-1, SHA-4, and nest arrangement respectively.

3. Experimental design

Adopting the randmized block arrangement, the acreage of a plot was designed to be 2.25 tsubo (9'×9'). The variety used for experiment was Norin-No. 41 which is remarkably pervaded in the Tohoku region, and the cultural operations from sowing to harvesting was carried out precisely in accordcance with the usual method.

4. Survey

In accordance with the advancement of growth in each experimental plot, the hills were sampled three times, i.e., at the end of the available tillering stage, the maximum tillering stage and the heading stage, for investigation of their plant height, tiller numbers and weight of dry matter (excluded roots) in rice plants. Growth analysis of plant harvested was also carried out.

III. General aspect of plant growth in 1956

Weathers during the rice growing season in 1956 were exceedingly favourable, the result of which brought about a bumper crop of rice plants throughout the Tohoku districts. Growth of rice plants in each experimental plot showed favourable development, in which case no impairments by insect pests were observed and the growth type of rice plants indicated longer stems and greater numbers of tillers as compared with the average year. Although the experimental plots with dense plantation of seedlings showed some lodgings, no damages were seen which were serious enough to disturb the experiment. Head sprouting was seen from August 13 through 18 (Average heading date : August 15) in all the experimental plots, but in the experimental plots with comparatively sparse plantation of seedlings the completion of head sprouting of rice plants was rather in disorder and delayed behind the date of August 18. Although the date of ripening fell on October 5 in each experimental plot, the actual harvesting was performed on October 8 simultaneously in the plots.

IV. Modes of hill arrangement and plant growth

Little difference of plant height between each spacing density as well as between modes of hill arrangement was seen up-to the end of availabel tillering stage. Although the plant height in the square hill arrangement with four-plant-

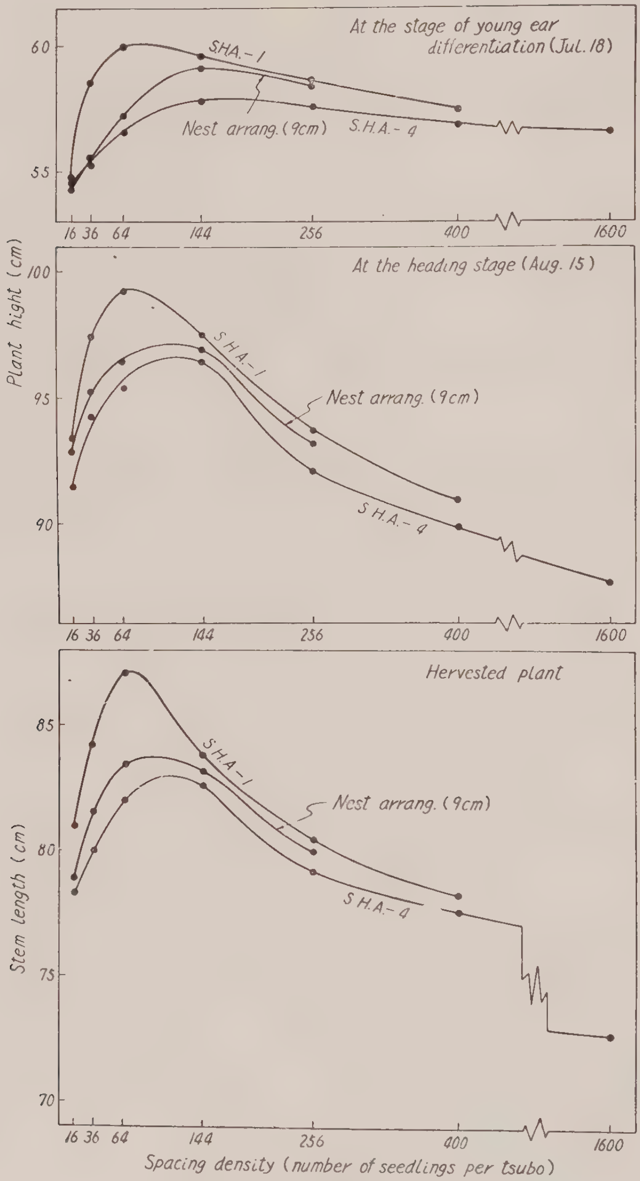

Fig. 2. Relation between plant hight and spacing density in various stage of growth.

planting per hill was somewhat higher in figures, this was due to the fact that the average value of the maximum plant height in the hill (among 4 individuals in a hill) was taken in case of the square hill arrangement with four-plant-planting per hill contrary to the average values of plant height in other experimental plots. This was due to the reason that the discrimination of each individual in the hill was hardly made by the investigation in field. Accordingly, in consideration of this fact, it may be appropriate to suppose the absence of difference between plant heights in each experimental plot, in addition to which no intervention upon plant height between individual plants would not come into existence toward this period.

The difference of plant height became clear gradually by the difference of spacing density and mode of hill arrangement during the period from the available

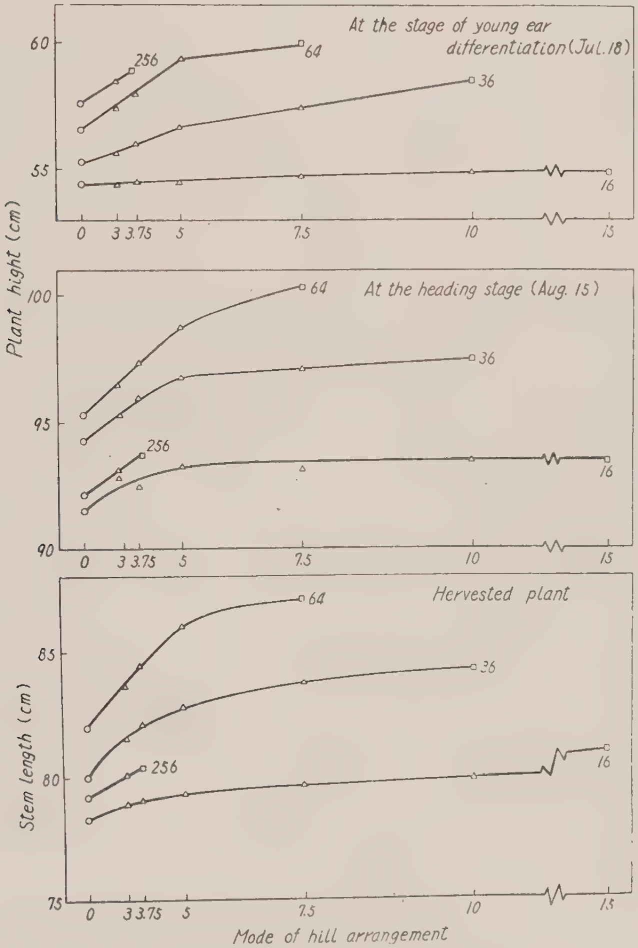

Fig. 3. Relation between plant hight and planting mode, figures in the graph show spacing density and o, △, and ▫ shows SHA-4, nest arrangement, and SHA-1 respectively.

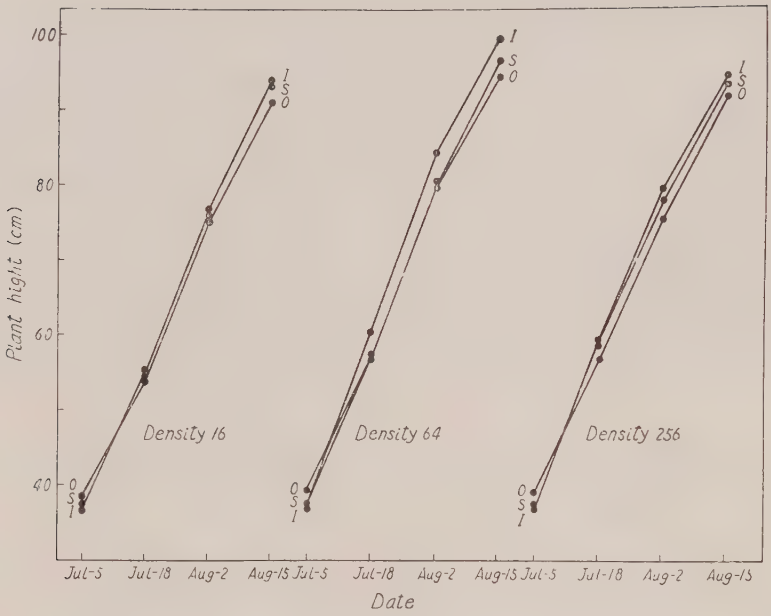

Fig. 4. Elongation of plant hight with progress of growth stage.

tillering stage to the maximum tillering stage. In other words, in the experimental plot with extremely rare density the plant height became taller along with the increase of spacing density, while in case of the square hill arrangement with one-plant-planting it attained maximum at the density of about 64 hills per tsubo and became lower gradually in proportion to the increase of spacing density. Although a similar tendency was shown in the "suue" or nest arrangement and the square hill arrangement with four-plant-planting, it was more remarkable in the case of the square hill arrangement with one-plant-planting per hill. Moreover, in the "suue" arrangement and the square hill arrangement with four-plant-planting the spacing density at which the plant height attained maximum was existent between 64–144 hills in the present experiment, being somewhat denser than in the square hill arrangement with one-plant-planting. Among various modes of hill arrangement, the plant height in the square hill arrangement with one-plant-planting was the tallest, followed by the plots of "suue" hill arrangement, and that in the square hill arrangement with four-plant-planting was the smallest. Such a relationship among various modes of hill arrangement became more and more remarkable in accordance with the increase of spacing density.

The relations between spacing density and plant height, and various modes of hill arrangement and plant height or elongation process of plant height along with development of growth can be seen in Figs. 2, 3 and 4. In order to avoid complication of the diagramatization, the presentation of the figure was restricted

to the cases of 9 cm individual spacing in the "suue" hill arrangement, being so with other figures below.

The number of tillers revealed interventions among individual plants at an earlier stage as compared with the plant height, and the difference of their number was already seen by mode of hill arrangement toward the end of the available tillering stage. However, difference of tiller numbers between different spacing densities was shown in the experimental plots with heigh density over medium degrees. Such a decrease of tiller numbers per individual plant with the increase of spacing density was not so remarkable until the maximum tillering stage, after which time the nullification of tillers became augmented gradually. Moreover, it was apparent that toward the heading stage the relations of spacing density with the number of tillers per individual plant and per unit area would take rather distinct orthogonal-asymptotical aspects.

The relationships of tiller numbers per individual plant and per unit area with various spacing densities and modes of hill arrangement were illustrated in Fig. 5 by different growth stage of rice plant, from which the above-mentioned aspcts

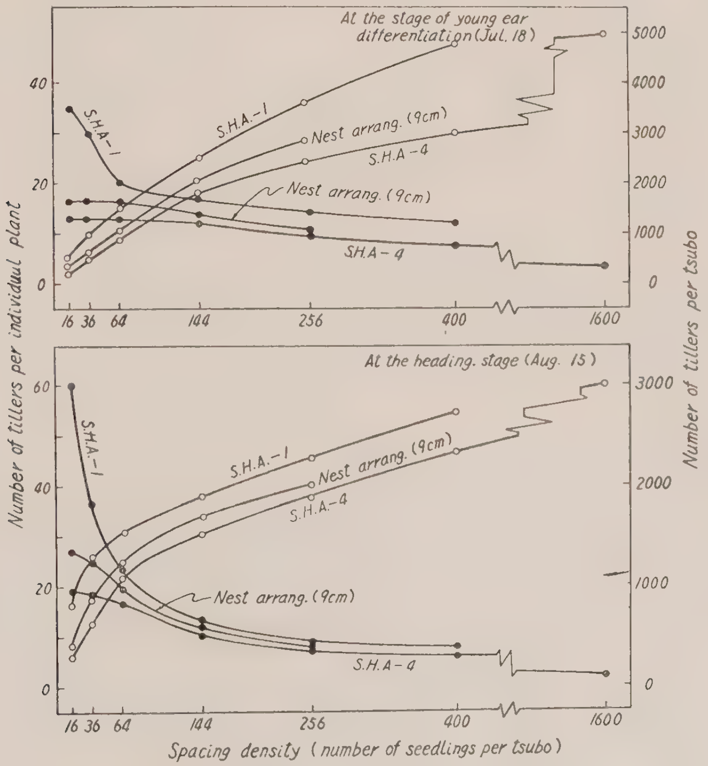

Fig. 5. Relation between spacing density and number of tillers per individual plant or per hill.

can be seen without difficulty. The number of tillers per individual plant showed a tendency of gradual increase with advancement of growth, and resumed a gradual decrease after the maximum tillering stage. However, as shown in Fig. 6, the maximum tillering stage became belated gradually according as the spacing density became thinner, that is, falling on and about July 18 in the experimental plot of

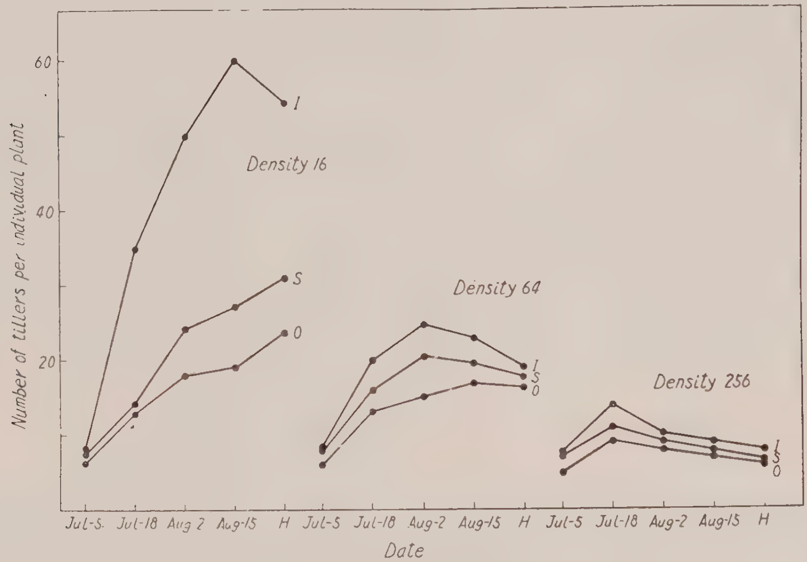

Fig. 6. Change of tiller numbers per individual plant with progress of growth stage.

heigh density with more than 144 hills per tsubo, on and about August 2 in the plot with 64 hills per tsubo, on and about August 15 in the plot of 36 hills per tsubo, and presenting no premature death of tillers in the plot of rare density with less than 16 hills per tsubo where the so-called maximum tillering stage was not observed.

Accordingly, as clearly shown in Table 2, the percentage of inavailable tillers

Table 2, Percent ratio of inavailable tillers to total number of tillers.

		Distance between individuals within hill								
		0	3	3.75	5	7.5	10	15	20	30
Number of seedlings per tsubo	4									0
	9								0	
	16	0	0	0	0	5.4	11.6	8.2		
	36	0	3.6	14.3	8.3	10.8	15.4			
	64	2.4	14.1	17.7	19.7	14.7				
	144	20.3	22.2	33.3	31.2					
	256	37.6	31.8	44.3						
	400	38.7	47.5							
	1600	52.8								

(percentage of premature death of tillers) was nearly naught in the experimental plots of rarest density, and increased gradually with the augmentation of spacing density. As regards the relationship between modes of hill arrangement and tiller numbers per individual plant, Fig. 7 illustrates that the number of tillers per individual plant was the greatest in the square hill arrangement with one-plant-planting and the smallest in the square hill arrangement with four-plant-planting, between which the "suue" arrangement was situated intermediately and the number of tillers per individual plant in the nest hill increased along with the augmentation of spacing density.

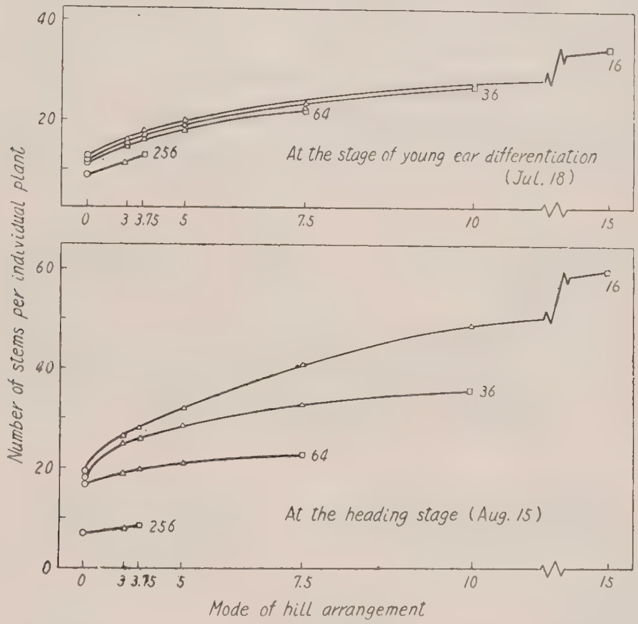

Fig. 7. Relation between number of tillers per individual plant and planting mode.

Moreover, the difference of tiller numbers per individual plant between the square hill arrangement with one-plant-planting and that with four-plant-planting became greater according as the spacing density became thinner. In other words, under the limited numbers of seedlings per tsubo the number of tillers per unit acreage was greater in the "suue" hill arrangement than the square hill arrangement with four-plant-planting, the square hill arrangement being greater than the "suue" arrangement, and such a tendency would be augmented in the plots of rarer density. When viewed the percentage of inavailable tillers (percentage of premature death of tillers) in Table 2, the percentage was the highest in the square hill arrangement with one-plant-planging and the lowest in that with four-plant-planting among various modes of hill arrangement, the modes of "suue" hill arrangement lying

between the above-mentioned modes of hill arrangement. On the other hand, as viewed the relationship between the premature death percentage of tillers and the spacing density, it is noteworthy that the augmentation of spacing density would result in an increase of the premature death percentage of tillers, and that the variation of the percentages by different mode of hill arrangement and the relationship between the percentage and the difference ot density seemed to present contradictory aspects.

V. Number of tillers per hill and spacing density of hills

As mentioned already, the description of plant height and tiller numbers in the preceding paragraph regulated spacing density to be the number of transplanted seedlings per tsubo and the modes of square hill arrangement with one-plant-planting and four-plant-planting as modified types of "suue" hill arrangement. However, it may be held that the square hill arrangement with one-plant-planting would constitute one hill with one plant, and the sqaure hill arrangement with four-

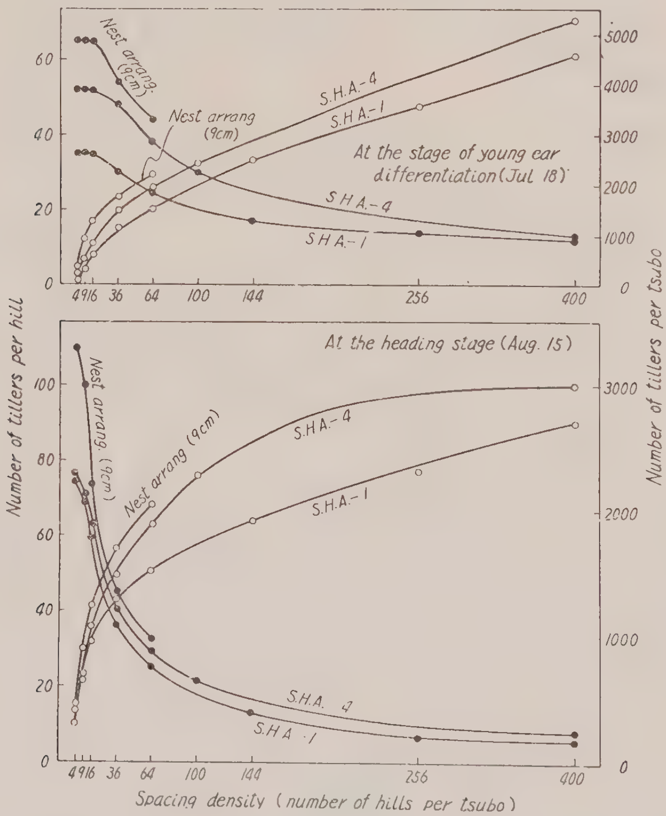

Fig. 8. Relation between number of tillers per hill and hill density.

plant-planting and the "suue" hill arrangement form one hill respectively with the assembly of four individual plants. In this concept, the number of hills per unit acreage is regulated to be the spacing density. As shown in Fig. 8, the relationship between tiller numbers per tsubo and the spacing density (numbers of hills per tsubo) was compared on the square hill arrangement with one-plant-planting, "suue" hill arrangement (9 cm) and the square hill arrangement with four-plant-planting from the above-mentioned viewpoint. The conditions in this case were so much different from the relationship in the preceding paragraph as to present reverse relative relations among the respective modes of hill arrangement, that is, the number of tillers per hill was the smallest in the square hill arrangement with one-plant-planting, then followed by that with four-plant-planting and was the greatest in the "suue" hill arrangement.

In the experimental plots of different "suue" arragement the number of tillers per hill became greater according as individual spacing in the hill was enlarged, and edged in with the quardruple value of tiller numbers per individual plant in the square hill arrangement with one-plant-planting in the course of approaching the above-mentioned mode of hill arrangement. The difference of tiller numbers among the modes of square hill arrangement with one-plant-planting and four-plant-planting and the modes of "suue" hill arrangment became greater in accordance with the rarefaction of spacing density and earlier periods of growth stages, while its difference between the square hill arrangement with one-plant-planting and that with four-plant-planting became exceedingly lessened at the harvesting stage as shown in Table 3.

Table 3. Number of tillers per hill at the maturing stage.

		Planting mode		
		SHA-1	SHA-4	nest arrange.
Number of hills per tsubo	4	90	94	124
	9	70	75	96
	16	55	60	70
	36	34	38	42
	64	21	23	26
	100		18	
	144	12		
	256	8		
	400	6	7	

These facts signify that the number of tillers per tsubo would increase in the order of square hill arrangement with one-plant-planting <square hill arrangement with four-plant-plating <"suue" hill arrangement under the equalized number of transplanted hills per tsubo. However, as the individual spacing became enlarged to approach the condition of square hill arrangement with one-plant-planting, it may be reasonable to regard each individual constituent as an independent

hill from the viewpoint in this paragraph. From such a standpoint, the number of tillers per unit acreage would be the smallerst in the "suue" hill arrangement, being great in the square hill arrangement with one-plant-planting, and was the greatest in the suqare hill arrangement with four-plant-planting. As such a spiral gradation theory can be established, the two dissenting views of the spacing density (either the number of transplanted seedlings or the number of transplanted hills) should not be oppositional but can be understood from an unificative standpoint through the mediation of the mode of "suue" hill arrangement.

VI. Tiller numbers per individual plant and per unit area, and law of density effect

As the general law of density effect, Kira[2] (1953) advocates the following power equation.

$$w \rho^a = K$$

As mentioned already, the decreasing tendency of tiller numbers per individual plant in accordance with the augmentation of spacing density demonstrated to be asymptotical in the domains with over certain spacing density, the tendency becoming more and more remarkable at later stages of growth.

This may suggest applicability of this empirical law to the relationship between tiller numbers per individual plant and spacing density. When plotted it on the

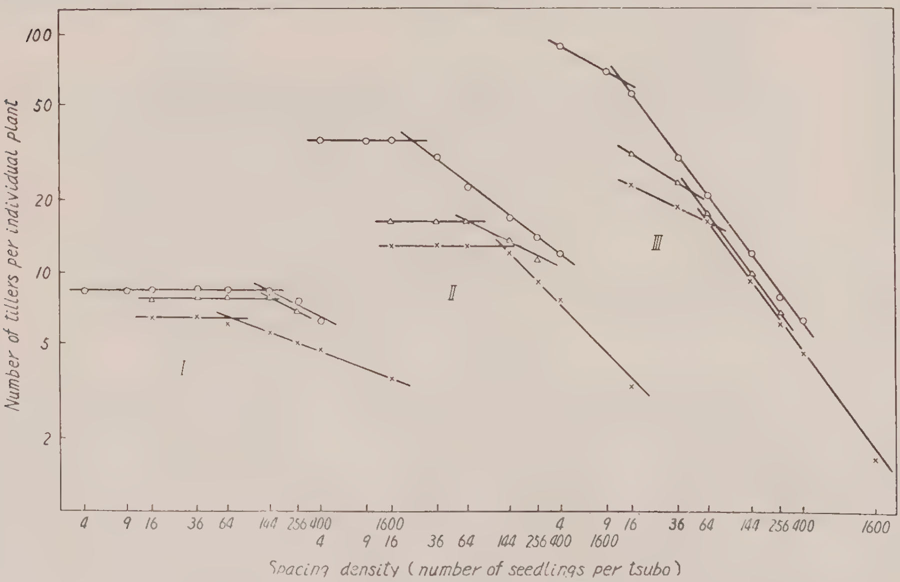

Fig. 9. Logalismic relation between number of tillers per individual plant and spacing density. I. II, and III shows end off stage of available tillering, young ear forming stage, and maturing stage respectively.

log-log diagram, the result was such as shown in Fig. 9. As evidenced in the figure, it seemed rather irrational to apply a straight line (on the graph of log-long scale) to the relationship between tiller numbers per individual plant and spacing density particularly at later stages of growth (afger elongation of young ears) even excluding the domains without competitive effect. With regard to the intensity of density effect, the domains of low and over medium densities can be divided into tow different domains, both of which are considered to be applied with two separate straight lines with different angular coefficients. As a matter of course, the entirely same relationship as in the above-mentioned case was recognized in the number of tillers per tsubo. It is needless to say that this should not signify domination of the laws of different density effects in the respective domains but merely the difference of values of the coefficients in figures. Accordingly, it may as well as considered that both domains are essentially are subject to a similar regularity. The possesion of different coefficients in the domains with rare and over medium densities may be proved by the fact that after the maximum tillering stage the number of tillers per individual plant would decrease in the plot of high density along with the nullification of tillers contrary to a gradual increase of tiller numbers per individual plant in the plot of rare density. In other words, the refractive index of the straight line indicating the marginal density between the domains of low density and high density would be differentiated by mode of hill arrangement, that is, 16 or so of individual spacing in case of the square hill arrangement with one-plant-planting, 36 or so in case of the "suue" or nest hill arrang-

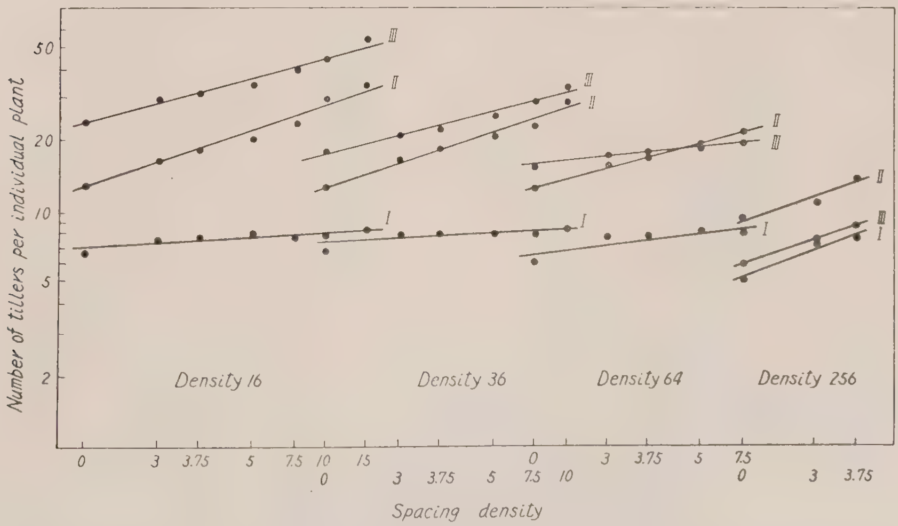

Fig. 10. Logalismic relation between number of tillers per individual plant and planting mode. I, II, and III shows end off stage of available tillering, young ear forming stage, and maturing stage respectively.

ment and 64 or so in case of the square hill arrangement with four-plant-planting, thus indicating a gradual transposition toward the sides of denser spacing. As compared these refractive indices with the percentage of ineffective tillers in Table 2 (see Fig. 10), it is noticeable that a close parallel relationship lay between the two cases.

As for the relationship between the number of tillers and the modes of hill arrangement, applicability of the above-mentioned power equation between the acreage of "suue" hills (reciprocal number of spacing distance in the hill) and the number of tillers per individual plant can be conjectured from Fig. 10. (Same results wil be derived from the use of spacing density in the "suue" hill instead of the acreage of "suue" hills.)

As mentioned above, the power equation of density effects may be safely applied to the relationship between the number of tillers per individual plant and the spacing density or the modes of hill arrangement. However, in the case of

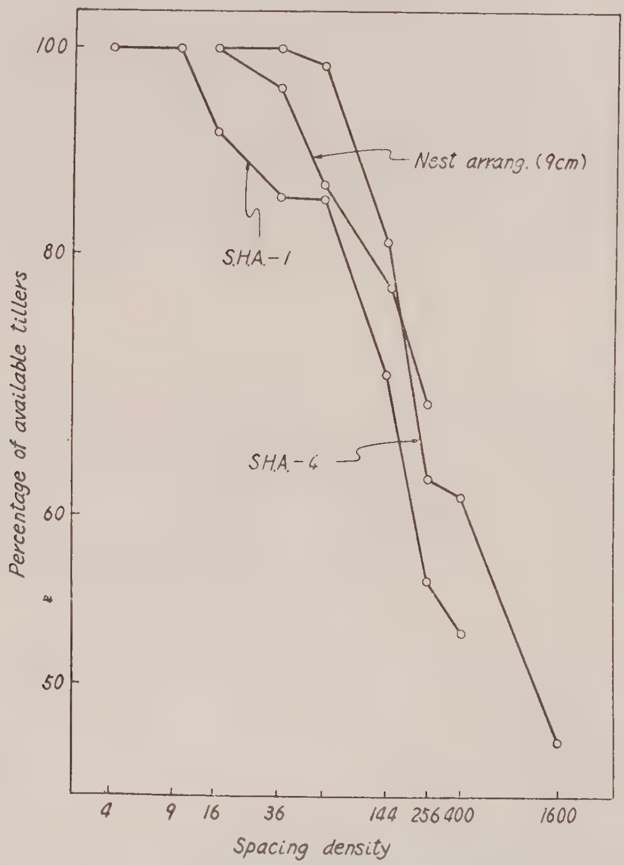

Fig. 11. Logalismic relation between available tiller percentage anb spacing density.

rice plants the expression of the relationship with a straigth line on the graph of log-log scale over a wide range of domains of rare density through high density should be somewhat irrational with the above-mentioned reason.

The percentage of available tillers; together with the ratio of grain weight to the whole plant weight, is regarded as a deciding factor for productivity of rice plants, the above-mentioned power equation, as is shown in Fig. 11, can not be applied to the relationship between the percentage of available tillers and the spacing density. This should be a matter of course, when viewed the periodic difference of the maximum tillering stage by the difference of spacing density.

VII. Spacing density and mode of hill arrangement, and dry weight of harvested plant

As shown in Figs. 12, 13 and 14, the variation of total weight, grain weight and straw weight of harvested plants in conformity with the changes of spacing density and modes of hill arrangement was little to be distinguished from the above-description on the number of tillers, and the diminishing conditions of their weight by the difference of spacing density and the increasing aspect of their weight are certain to represent an asymptotical situation in all the modes of hill arrangement.

As compared the respective modes of hill arrangement under the same spacing density, the yiled of the square hill arrangement with one-plant-planting was the

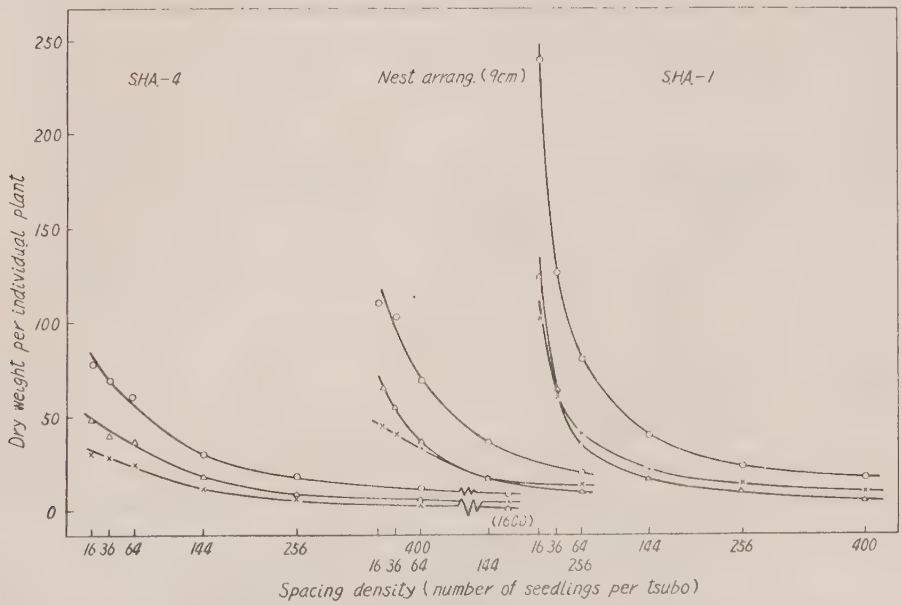

Fig. 12. Relation between dry weight per individual plant and spacing density : ○, △, and × shows whole weight, grain weight, and straw weight respectively.

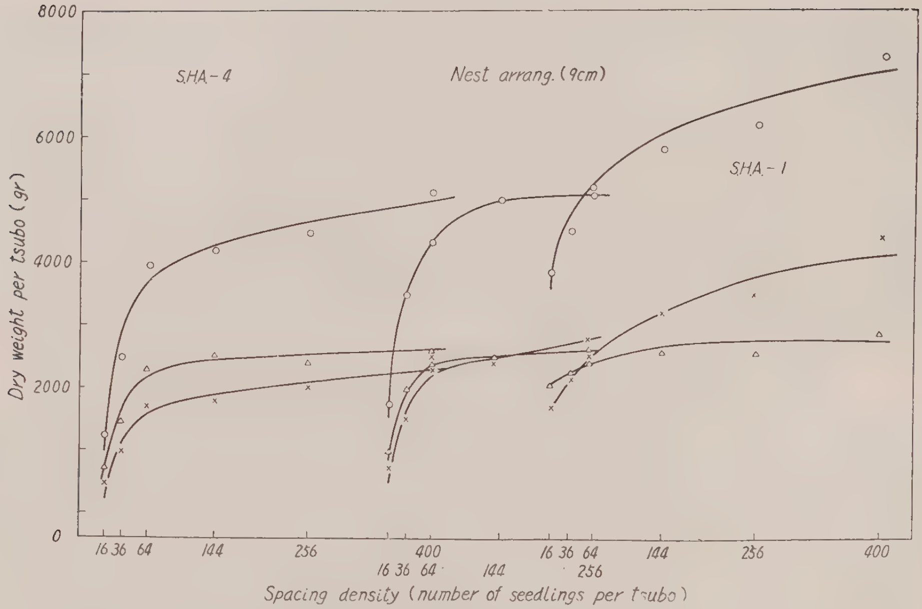

Fig. 13. Relation between dry weight per unit area (1 tsubo) and spacing density: o, △, and × shows whole weight, grain weight, and straw weight.

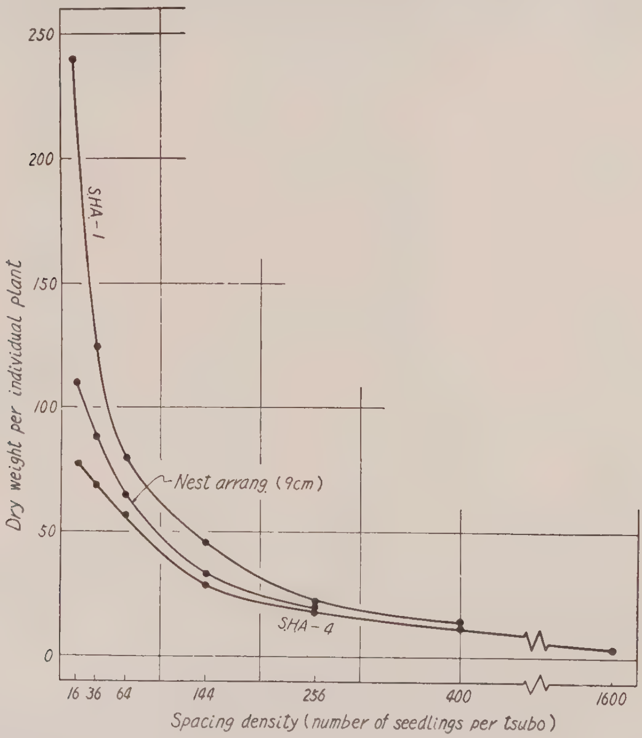

Fig. 14. Relation between dry weight per individual plant and planting mode.

highest even on the whole plant weight, grain weight and straw weight, various modes of "suue" hill arrangement lying intermediately, and the yield of the square hill arrangement with four-plant-planting was the lowest. Such differences among the modes of hill arrangement was decreased by the increase of spacing density.

VIII. Constitutional elements of yield and density effect

As shown in Fig. 15, the relationship between total weight, grain weight and straw weight per individual plant and spacing density on the graph of log-log scale took the forms to which separate straight lines were applicable in the domains

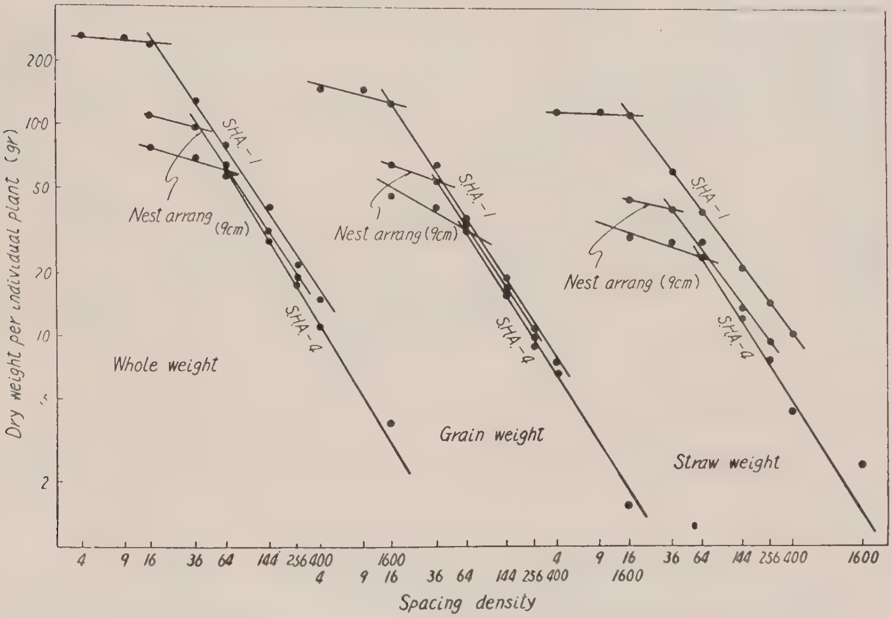

Fig. 15. Logalismic relation between dry weight per individual plant and spacing density.

with low and over medium densities as in the above-mentioned case of tiller numbers per individual plant. Accordingly, the power equation may be considered applicable in the respective domains with different spacing density. The same condition was seen in each yield calculated in terms of unit acreage (Fig. was omitted). Shinozaki et al[3] (1956) adovocate the application of reciprocal equation ($1/W=A\rho+B$) following the power equation of density effect, that is, the applicability of rectineality to the experimental values in the domains close to non-competitive density and the domains adjacent to the refractive point of two separate straigth lines can be improved by the reciprocal equation to such a extent that the fitness with a straight line can be expected in all the domains ranging from

rare density to high density excluding the domain under non-competitive density effect.

As computed the deviation from regression in case of the rectilinear application to all the domains with different spacing density for comparison of the adaptability between the power equation and the reciprocal equation, no great difference was

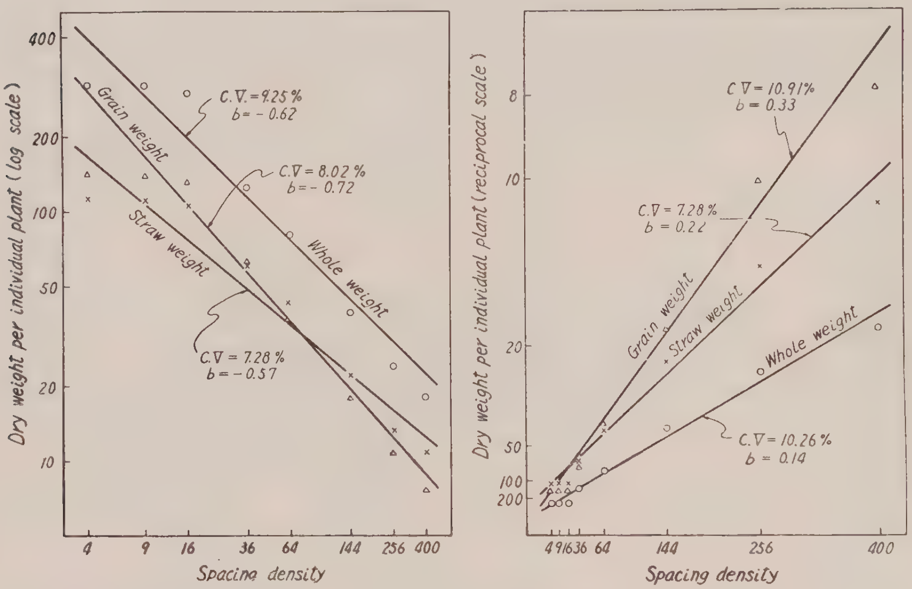

Fig. 16. Comparison of goodness of fit betwen power equation and reciprocal equation.

Table 4. Regression coefficients and C. V. from regression (in case of SHA-1)

	Whole weight		grain weight		straw weight	
	b.	C. V.	b.	C. V.	b.	C. V.
Power equation	0.62	9.25	0.72	8.02	0.57	7.28
Reciprocal equation	0.14	10.26	0.33	10.91	0.22	13.71

Tabel 5. Regression coefficients and C. V. form regression (in case of SHA-1)

	$\log y = a \log x + \log b$		$\frac{1}{y} = ax + b$		$y = \frac{ax+b}{a'x+b'}$	
	b.	C. V.	b.	C. V.	b.	C. V.
Whole weight	0.82	1.02	0.14	10.00	0.41	2.14
Grain weight	0.90	1.39	0.33	10.36	0.75	0.61
Straw weight	0.73	1.61	0.22	13.46	0.97	1.04

seen between the two cases suggesting weakness of the reciprocal equation in improving the rectilinear application. The illustration of examples in case of the square hill arrangement with one-plant-planting was given in Fig. 16 and Table 4. Moreover, as compared the applicability of the domains of high density from the refractive point to $y=Ax+B/A'x+B'$ by the power equation, the reciprocal equation and the remainder commutation with the deviation coefficients in regression line by the commutation of the respective co-ordinates, the results were such as shown in Table 5, and the deviation coefficient in case of the reciprocal equation was greater than other two cases, being a little to be different from the coefficients in case of the rectilinear application with a straight line to all the domains of diffeient spacing density. In this experiment, it was considered more appropriate for expression of the relationship between weight of dry matter and spacing density to apply the power equation or to whole plant weight, grain weight and straw weight rather than the application of the reciprocal equation. In addition, this condition was also applicable to the above-mentioned tiller numbers per individual plant.

With regard tc the relationship between the change of hill arrangement and the weight of dry matter per individual plant, the formation of a power equation was recognized as in the case of tiller numbers per individual plant. Fig. 17 illustrates the condition of its applicability. As evidently seen in the Fig., it is

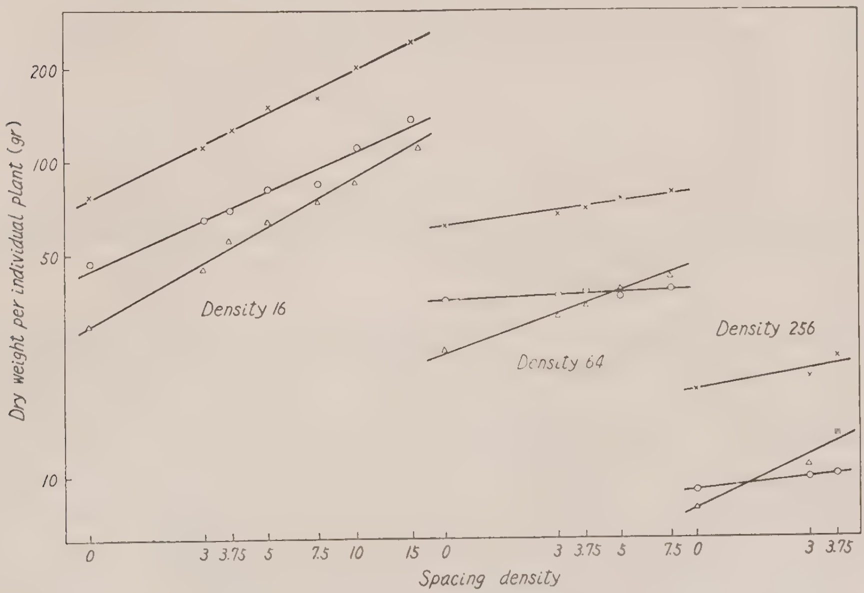

Fig. 17. Relation between dry weight per individual plant and planting mode : ×, o, and △ shows whole weight, grain weight, and straw weight respectively, scale of abscissa is shown by log x^2 and where x shows distance between individuals within the hill.

a characteristic that the difference of grain weight along with the increase of spacing density among various modes of hill arrangement became smaller relatively.

IX. Hill density and yield per hill

As in the above-mentioned case of tiller numbers, comparison of the variation of dry weight of harvested plants by the increase of hill numbers per tsubo among the square hill arrangement with one-plant-planting, the square hill arrangement with four-plant-planting (composed of 4 individual plants) and the "suue" hill arrangement was given in Fig. 18, that is, in the domains of comparatively rare

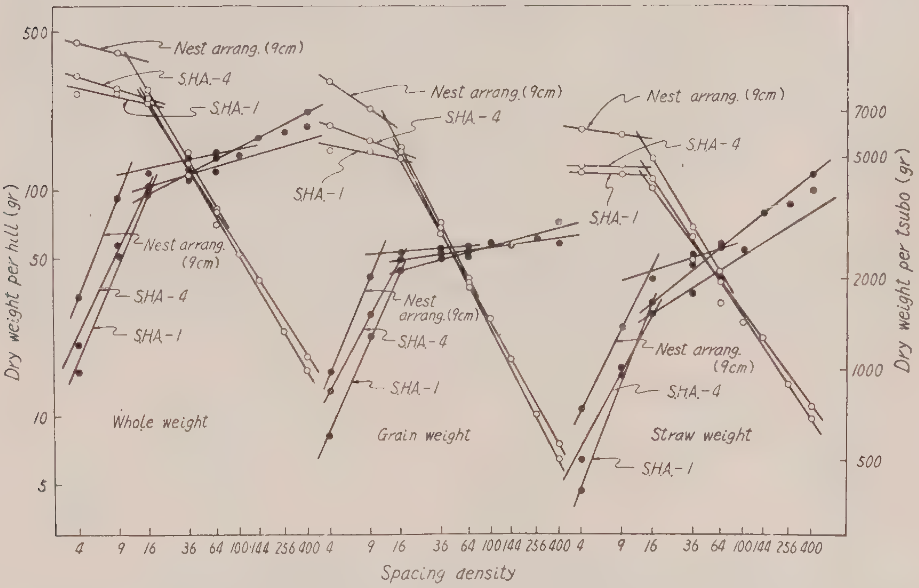

Fig. 18. Logalismic relation between yield and hill density : o and • shows dry weight per hill and dry weight per unit area (1 tsubo) respectively.

density the whole plant weight, grain weight and straw weight in case of the yield per hill were the highest in the "suue" hill arrangement, followed by the square hill arrangment with four-plant-planting and the lowest in the square hill arrangement with one-plant-planting, but this relationship was reversed in the domains with over certain density to indicate a larger yield in the square hill arrangement with one-plant-planting than that with four-plant-planting. In this respect, this case was considerably different from the case of tiller numbers. The spacing density of hills at which inverted the relationship with the square hill arrangement showed some difference in the yield of each portion, the conversion density being 36 hills in case of the whole plant weight, 64 hills in case of the grain weight and 13 hills and so in case of the straw weight. The same thing can

be said for the yield calculated in terms of unit acreage. Among the whole plant weight, grain weight and straw weight, the conversion density of the grain weight was the highest at a spacing density close to 64 hills per tsubo. Accordingly, in case of the spacing density over 64 hills per tsubo, the maximal distnace of individual spacing would be 9 cm in the "suue" hill arrangement with 100 hills per tsubo, which is equivalent to the square hill arrangement with 400 hills per tsubo. Therefore, as the "suue" hill arrangement with over 100 hills per tsubo should be out of consideration in practice, the mode of square hill arrangement with one-plant-planting in case of the plantation of high density may be regarded as the mode of hill arrangement which produces the greatest quantity of grain yield.

X. Ratio of grain weight to whole weight and spacing density

Although the ratio of grain weight to whole weight is regarded as an important trait for determination of productivity, a linear relationship between the

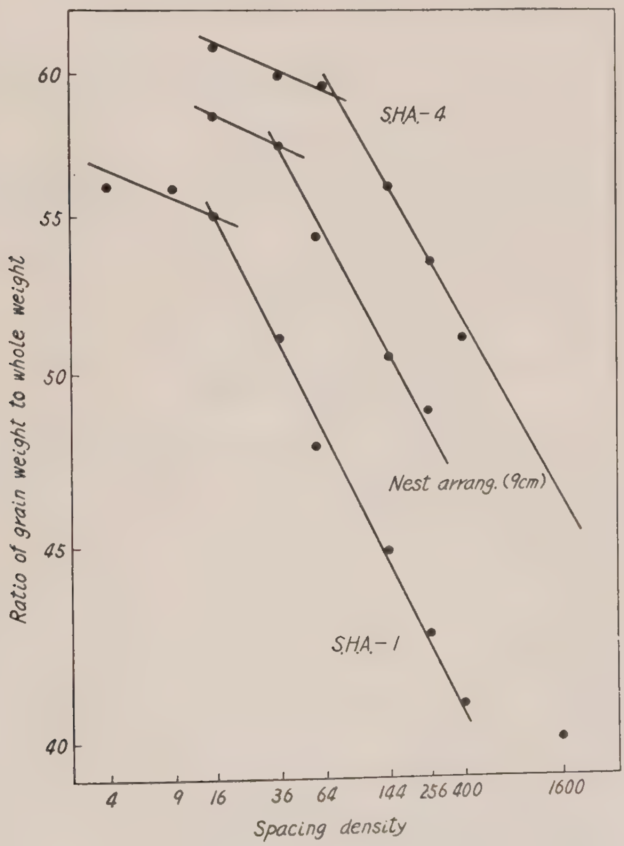

Fig. 19. Relation between percent ratio of grain weight to whole weight and spacing density (log-log diagram).

ratio of grain weight and the spacing density was seen on the graph of log-log scale as shown in Fig. 19. As the ratio of grain weight to whole weight was the quotient divided grain weight with whole plant weight, it is a matter of course that the ratio of grain weight should follow the power equation if the power equation of density effect could be constituted either for grain weight or whole plant weight. Therefore, although its diagrammatization was not particularly neceassary, it was posted herein in order to demonstrate the relative relationship among each mode of hill arrangement. Among the respective modes of hill arrangement, the ratio of grain weight was the lowest in case of the square hill arrangement with one-plant-planting, being the highest in that with four-plant-planting, and the "suue" hill arrangement lay between the two. These relations wer entirely the same as the percentage of available tillers. However, as the fall of available tiller percentage can be hardly regarded as the direct cause for the fall of grain weight ratio, the condition by which the ratio of effective tillers was decreased may as well be considered to be an element for lowering the ratio of grain weight to whole weight.

The ratio of grain weight to whole weight was lowered by the augmentation of spacing density, the fall of which showed no great difference among each mode of hill arrangement. On the other hand, the increase of the acreage in the "suue" hill brought about the fall of the grain weight ratio in case of the "suue" hill arrangement, presenting a strange phenomenon by a glimpse. This respect took the same process as the above-mentioned percentage of effective tillers, and it may be noteworthy that the augmentation of "suue" acreage does not necessarily mean the rarefaction of spacing density contrary to the parallel relationship between the two in the above-mentioned number of tillers.

XI. Average grain weight per ear and weight of ear on main stem

Applicability of the power equation of density effect to the number of tillers and the weight of grains per individual plant is, as stated already, proved separately in the two domains with rare density and high density. The grain weight per individual plant being indicated with the product of the number of tillers per plant and the average weight of a grain, the power equation is applicabls to the average, grain weight per ear. It is also understood that similar relations to the Huxley's law concerning the partial weight was seen between the number of tillers per individual plant and the average grain weight per ear. As similarly the grain weight per unit acreage is the product of the average grain weight per ear and the number of tillers per unit acreage, relation between the spacing density and the grain weight per unit acreage should also follow the power equation if the density effects of the two can be expressed with the equation.

For the average grain weight per ear $g = Ax^{-a}$

For the number of tillers per plant $N = Bx^{b}$

If the above-mentioned formluae can be established, the power equation of density effect shall be for the yield per plaut

$$y = g\,N = A\,B\,x^{a-b}$$

Accordingly, the yiled per tsubo would be increased with spacing density if b>a, and the increase of spacing density would bring about a gradual decrease if b<a. As mentioned in the previous paper, it is not seldom that the yiled of grains of rice plants would be converted to decrease over a certain degree of spacing density which was set as its peak. This is considered due to the reversion of b<a relationship into b>a. In the domain of rare density the average weight of a grain was increased by the augmentation of spacing density (decrease of tiller numbers), but it was decreased along with the increase of spacing density (decrease of tiller numbers) at a denser degree beyond certain spacing density. As shown in Fig. 20, applicability of the power equation was favourable for the grain weight of the ear

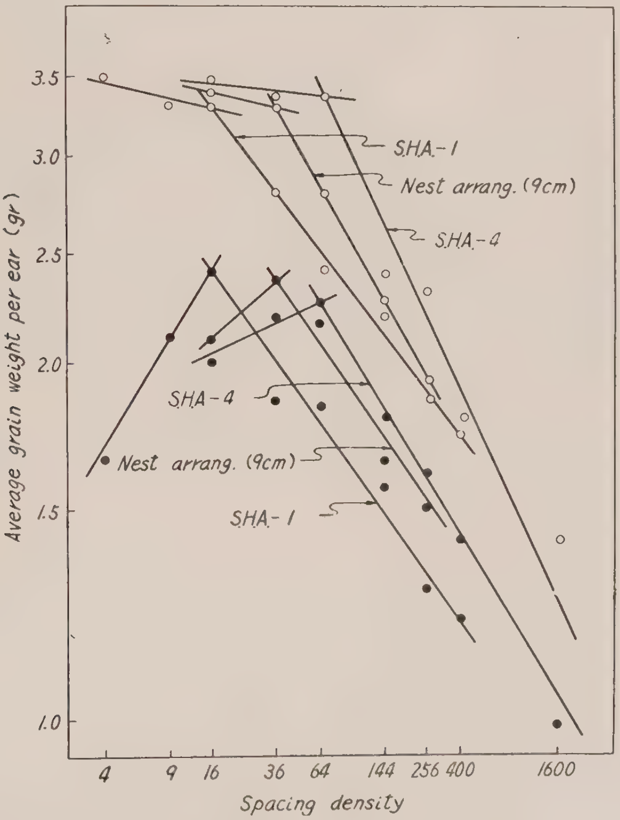

Fig. 20. Relation between average grain weight per ear or weight of ear on main stem and spacing densety : • and ○ shows average grain weight per ear and weight of ear on main stem respectively.

on the main stem. Thus, the power equation is considered to be an universal and appropriate empirical law as an expression formula of density effect on various characteristics of rice plants.

As seen in the figure, the difference between the grain weight of the ear on the main stem and the average weight of grains per ear became smaller according as the spacing density became denser. This to signify great differences of grain weight among each stem constituting individual plants in accordance with the rarefaction of spacing density, but it is evident that it does not necessarily bring about the fall of production efficiency, in view of the ratio of grain weight to whole weight and the ratio of available tillers to total tillers per hill.

XII. Summary

1. In the previous paper the effect of spacing density on growth and yield of rice plants was examined under different spacing densities of the square hill arrangement with one-plant-planting per hill. In order to determine relative effects among a variety of modes of hill arrangement from the viewpoint of the yield, the author made investigations in this paper on the interrelationship between degrees of spacing density and modes of hill arrangement ranging from the square hill arrangement with one-plant-planting to the square hill arrangement with four-plant-planting through the "suue" or nest hill arrangement. This experiment was carried out at Kashimadai Farm, Institute for Agriculatural Research, Tohoku University in 1956.

2. The difference of plant height between each spacing density and each mode of hill arrangement came into existence gradually on and after passing the available tillering stage. In the domain of rare density the plant height became taller in accordance with the increase of spacing density and attained maximum at a ceratin degree of density beyond which it became smaller.

Among the respective modes of hill arrangement, the plant height was taller in the following order.

S.H.A. with one-plant-planting per hill < "suue" hill arrangement < S.H.A. with four-plant-planting.

3. Interference among individual plants were seen in the number of tillers at an ealier stage than the case of plant height.

An asymptotical relationship was existent between the number of tillers per individual plant and spacind densities, to which the power equation of density effect by Kira et al was satisfactorily applicable.

Being independent of spacing density among each mode of hill arrangement,

S.H.A. with one-plant-planting < "suue" hille arrangement < S.H.A. with four-plant-planting.

was in order of being greater in the number of tillers per individual plant, and the power equation of density effect was applicable between the modes of hill ar-

rangement and the number of tillers per individual plant.

4. As regards the relationships of spacing density with the total weight, grain weight and straw weight of harvested plants, the fitness of the power equation was more favourable than the reciprocal equation.

5. The power equation of density effect was also applicable to the ratio of grain weight to whole weight and the average grain weight per ear.

6. As mentioned above, the porew equation was distinguished as the expression formula of density effect in rice plant, being favourable for its applicability to experimental values.

However, it seemed difficult to represent the relationship between various characteristics of rice plants and spacing densities by single straight line on the log-log diagram throughout a wide range of domains from rare density to high density. Therefore, it seemed reasonable to express these domains with two different straight lines having different angular coefficients by discriminating the domain of rare spacing density with an extremely low available tiller percentage from the domains of medium spacing density.

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Studies on the Vegetative Succession in Natural Crassland

Particularly on the production and germination of *Miscanthus sinensis* seed

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and Noboru Nishimura
(Received on February 10, 1958)

I. Introduction

The authors have reported the plant succession of *Bokuya* (natural grasslands) in this country in the previous paper[1][2]. In addition to the occurrence of such a plant succession in *Bokuya*, there are observed some grasslands which indicated a long-pending duration. For example, some of *Miscanthus type grasslands* as grass cutting lands and *Zoysia* and *Sasa type grasslands* as grazing lands have lasted several decades and sometimes over one hundred years. In these cases, although the stabilization of vegetation may be effected under a given condition, it has not been made clear whether the cause for such a protrated duration of *Bokuya* should be attributed to the stability of vegetation due to durability of grasses, in other words, the maintenance of the same vegetation through the asexual reproduction of plants or the sexual alternation of generations. Thus, the question of substance on the phenomenon of stability of vegetation should be taken into consideration. In spite of the frequent use of words "stability of vegetation or productive vegetation", their specific contents have not been sufficiently analyzed on the grasslands in this country at least. The method of deferred and rotation grazing by A.W. Sampson[7] et al aims to maintain vegetation by efficient reproduction of seeds, and has achieved success in grasslands comprised of short-lived grasses. However, the applicability of this method to *Bokuya* in this country which are comprised of longlived grasses is still dubious. Although this problem is interesting ecologically, it is also of great importance agronomically for deriving a principle a suitable pasture management on the basis of the maintenance and augmentation of productivity. In view of the unfavourable results of germination of seeds in a series of laboratory experiments from 1952 by a considerable inhibition of dormany of wild plant seeds, the authors felt the necessity of clarifying the relationship of the plant succession of these seeds with their productivity, distribution, germination and development. In pursuit of a series of the above-mentioned phenomenon

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in connection with the managment of *Bokuya*, the authors have carried out investigations from 1955 of each growth stage of seeds on the production, migration, germination and development of *Miscanthus sinensis* which is one of the most dominant grasses in *Bokuya* of this country. This paper is based on the results of 1955 and 1956 investigations, by which several points pertaining to this problem were known.

Recently the reclamation of *Bokuya* into an intensive artificial grassland takes place prevalently, where the competition between forage grasses and wild plants is unavoidable as pointed out already[3]. It is a great pleasure for the authors, if this paper can contribute to clarification of the problem concerning the migration of wild plants into the reclaimed grassland.

The authors wish to express their gratitude to the Ministry of Agriculture and Forestry for the grant of expenses for accomplishment of the present study.

II. Experimental Method

The present survey was carried out chiefly on the number of ears, number of seeds, ways of distribution and number of germinated seeds of *Miscanthus sinensis* under various conditions such as grazing of cattle, grass cutting and branding. In order to grasp the general conditions of *Bokuya* (1,223 acres) attached to the Agriculture Department, Tohoku University, selection was made of areas of different vegetation. It is necessary to study in a limited area may bring about detailed values of various phenomena which come into existence under complicated conditions of geographical features, location, the direction of the wind, rainfalls and flows of rainwater, and furthermore vegetation, fertility, grazing, grass cutting and branding, but eaquary necessary to know general data in wide area. The authors selected the latter case and performed the present survey in the overall condition of a wide area of *Bokuya*. Investigated items and experimental methods are as follows.

The investigation on the number of stems and the height of plants was made at the end of September, 1955, and other investigations were performed in 1956.

1. The number of seeds in grazing lands and mowing lands

(i) Investigation of vegetations

10～20 quadrats of 1 m^2 were sampled from 11 plots (grazing lands : 8 plots, mowing lands : 3 plots) selected from the entire area of the *Bokuya*, vegetations of which were investigated by the total estimation method.

(ii) The number of ears of *Miscanthus sinensis* per 1 m^2 quadrat

The number of grazed stems, inavailable stems, late sprouting stems and plant height of *Miscanthus sinensis* were probed in the quadrats subject to the investigation of vegetation, in addition to the number of stems.

(iii) The number of seeds

By sampling all the ears in the same quadrat, the weight of ears, length of ears,

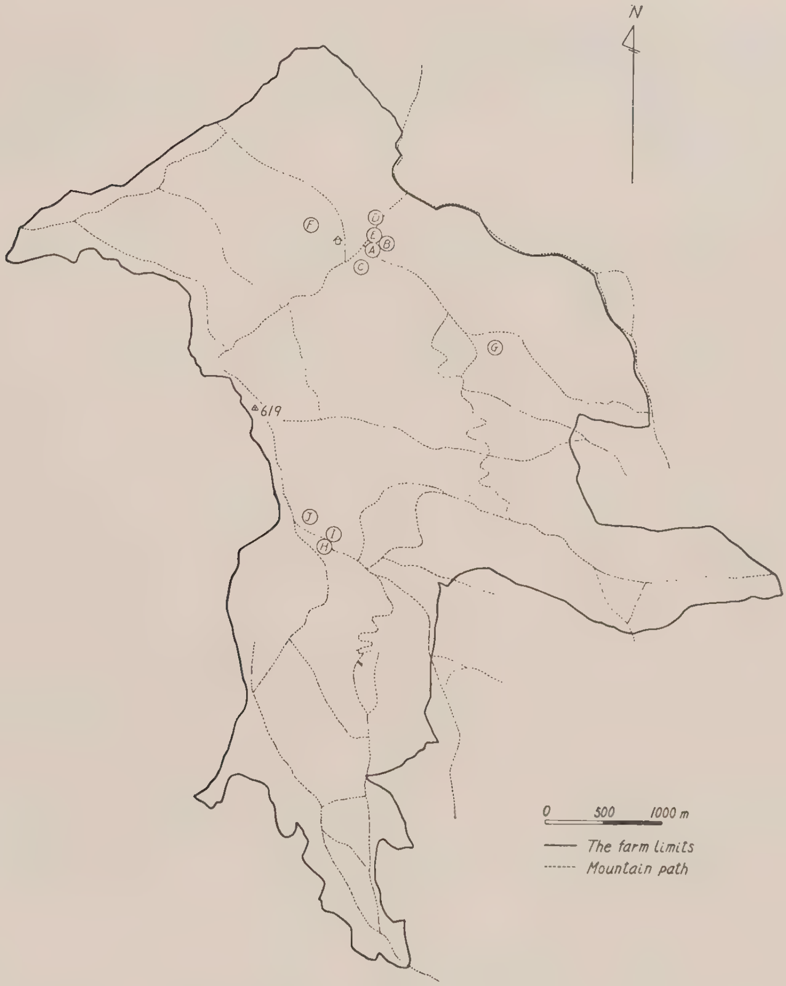

Fig. 1. The situation of researching plot in Kawatabi Farm.

glume, number of ear branches and number of seeds were investigated on the ears of *Miscanthus sinensis* (including ears partially grazed by cattle).

2. The number of migrated seeds

As for the number of migrated seeds of *Miscanthus sinensis*, an investigation was made on the number of seeds contained on the surface of soils or inside the soils.

(i) The number of soil sampling spots

The random selection of one spot was made in each plot subject to the abovementioned investigations, then sampled soils in 15 spots in total which were comprised of 5 spots in a row at a distance of 5 m from the given spots and their

neighbouring spots in two rows at a distance of 5 m.

(ii) Amounts of sampling soils

Employing a sylinder in a diameter of 10 cm, soils were sampled in the depth of 1 cm as the standard. However, as rizomes made difficult the sampling of soils in the exact depth of 1 cm, there were some cases in which the depth of sampling ranged 2 cm or beyond it.

3. The detection of seeds in soils

(i) Among several studies such as R. Robinson[8] applied the washing concentration, but we employed K_2CO_3 50% solution (specific gravity 1.4) for separation of soil granules and seeds[4,5]. However, as soils of *Bokuya* contain a large quantity of organic matters, the authors produced the sedimnetation of soils with the repeated use of a large quantity of solutions, following which the suspension was removed on a gauze and washed with water, then seeds were selected for determination.

(ii) Examination of germination capacity of seeds

As a long hour disposition of seeds in K_2CO_3 resulted in inhibition of their germanation[5], the examination of germination capacaity of seeds was not carried out.

4. Natural germination of *Miscanthus sinensis* seeds

Having selected J plot in mowing land for the purpose of this investigation, the plot was subdivided into the branding section and the nonbranding section, and the upper side and the lower side of the slope, where the number of young plants of *Miscanthus sinensis* which survived by the first part of October in 10 pieces of 1 m² circular quadrats of the subdivided sections was made the number of the seeds in natural germination. Consequently, the plants which withered after germination were excluded from the investigation.

III. Result and Discussion

1. Investigation of vegetations

The vegetations of A,B, ... G Plots in the pasture land were given in Table 1. The time of investigations ranged from the latter part of September to the first part of October. As vegetations after grazing of cattle, the relatively low revelation of dominance of *Miscanthus sinensis*, *Zoysia japonica* and other forages can be presumed. In addition, vegetations of the grass cutting lands were given in Table 1 (plot H～plot J). Mowing of these grass fields has not been made last year and this year. In the past the pasture land had grazed 50 horses during a period of 1943～1944, but was not utilized from 1945 to 1952 and remained untouched except branding once a year. As the result, *Miscanthus sinensis* grew so tall as 2 m in the year of 1952 to convert the pasture land into a *Miscanthus type grassland.* However, 47 Japanese indigenous black cattle and 3 milking cows in a total of 50 cattle, 60～70 cattle and 85 cattle were grazed in an unrestricted way in 1953

1954 and 1955 respectively. As a result of such a free grazing, an partially excessive utilization of the land was occasioned the vegetation as in C plot. The grass fields had not been utilized until 1952, after which time mowing took place once a year between late in August and early in September although there were unmown places yearly. In short, as viewed the vegetation of each plot, A plot was a *Pteridium-Zoysia-Miscanthus type grassland* and B plot a *Pteridium-Miscanthus type grassland*. Although both A plot and B plot abounded in *Pteridium aquilinum*, *Zoysia japonica* was numerous in A plot contrary to its scarcity in B plot, and *Miscanthus sinensis* was somewhat more dominant in B plot than A plot. C plot was a *Pteridium-Zoysia type grassland*, in which the dominance of *Miscabthus sinensis* ranked the 3rd place. This plot was easy of access for cattle as their flocking spot to be called "umatateba". The inferiority of grass development in the plot stands to reason under such conditions. Although D plot was a *Miscanthus type grassland*, it may be called a *Miscanthus-Astilbe type grassland* sometimes due to the abundance of *Astilbe thunbergii*. As a result of the location of northwestward slope, the plot was difficult of access for cattle, where the growth condition of *Miscanthus sinensis* was distinguished and the number of stems grazed by cattle was the samllest. E plot was a *Miscanthus-Pteridium type grassland*. Although the plants were considerably grazed by cattle, the height of plants showed a good development in the plot and *Miscanthus sinensis* tended localize sporadically in a way of forming a big plant. F plot was a *Miscanthus-Pteridium type grassland*, where the average number of stems was comparatively large and the growth condition of plants was fairly well. G plot underwent branding early in June, 1955, by which young shoots of plants were burnt down. As the regenerated plants were affected by grazing of cattle from the latter part of July to August, the vegetative condition of the plot was exceedingly devastated in 1955 in spite of the yearly good development of *Miscanthus sinensis*. Consequent on this cause, none of ears on the stems was observed in the plot. F plot was a mowing land dominated by *Miscanthus sinensis*. I plot was also a *Miscanthus type grass* land. J plot was a *Pteridium-Miscanthus grassland*, but was extremely inferior in vegetation as a mowing land.

2. Ecological condition of *Miscanthus sinensis* in the pasture land and mowing land

As explained in the preceding paragraph, investigations of the ecological condition of *Miscanthus sinensis* as a consistent phenomenon on a wide ranged area were made in the pasture land and mowing land. Although the effect of grazing and mowing upon *Miscanthus sinensis* can be made clear in comparison with any autoecological researches of *Miscanthus sinensis* in the past, the lack of such a work made it impossible to analyze their effect. However, this paper may be useful for knowing part of the ecological phase of *Miscanthus sinensis* in *Bokuya* in Japan. Moreover, as *Miscanthus sinensis* reacts on the intensity of grazing,

mowing and branding, the data herein described should be regarded as one of the ecological phase in the Kawatabi Experimental Farm.

(i) Number of ears

As the effect of grazing and grass cutting on various phenomena of *Miscanthus sinensis* from earing physiology and production of seeds through germination of seeds comes into guestion, it is, first of all, necessary to briefly explain the actual condition of cattle grazing during the year of investigation. However, as free grazing, cowmen were assigned only to prevent cattle from going outside the pasture land, so that the details of grazing were unknown. The number of cattle grazed during the year was 77 cattle and the acreage of the pasture land was about 1,223 acres. As the cattle were grazed freely from morning till night between the first part of June and the latter part of September, they behaved in a herd or individually at liberty in the entire area. According to the cowmen, the period when a number of cattle had entered the area subject to the present study (or its neighbourhood) is illustrated in Table 2. However, the period and the frequency do not necessarily indicate the degree

Table 1. Vegetation

Name of plants	A plot	
	d	f
Arundinella anomala		
Calamagrostis arndinacea var. scinroides		
Eriochloa villosa	+	5
Miscanthus sinensis	1.8	90
Sasa sp.	0.3	45
Spodiopogon cotulifer		
S. sibiricus		
Zoysia japonica	1.9	90
Achillea sibirica	+	5
Adenocaulon bicolor var. adhaerescens		
Anaphalis margaritacea		
Artemisia japonica	0.2	60
A. vulgaris var. vulgatissima		
Aster scaber		
A. pinnatifidus		
Cirsium spicatum		
Gerbera anandria		
Gnaphalium hypoleucum	0.2	25
Eupatorium lindleyanum		
Patrinia scabiosaefolia		
Solidago virgaurea		
Sonchus oleraceus		
Compositae		
Microlepia pilosella		
Pteridium aquilinum	2.7	95
Osmunda japonica		
Geum japonica		
Potentilla fragarioides var. sprengelians	0.7	100
P. freyniana		
Robus morifolius		
R. triphyllus		
R. microphyllus var. incisus		
Disporum smilacinum	+	5
Hosta japonica var. coerulea		
Smilax china		
Iris sibirica var. orientalis		
Lycopus virginicus var. parviflorus		
Clinopodium chinense		
Swertia japonica	0.6	85
Dracocephalum argunense		
Gentiana axillariflora		
Carex lanceolata		
Carex sp.	0.3	25
Euphorbia pekinensis var. japonica		
Salix caprea		
Populus sieboldiana		
Geranium nepalense		
Rhododendron obtusum var. kaepfeli		
Lespedeza juncea var. sericea	0.7	90
L. bicolor	0.1	40
Halorrhagis micrantha	0.7	70
Astilbe thunbergii var. congesta	0.4	30
Parnassia palustris	+	15
Hydrocotyle wilfordi	0.3	45
Lysimachia clethroides	0.3	45
Diervilla hortensis	0.1	5
Viola sp.	0.1	15
Hypericum erectum	+	5
Platycodon grandiflorus		
Scabiosa japonica		
Thalictrum minus var. elatum		

note : d : average of dominance, f : average

of each plots.

B plot		C plot		D plot		E plot		F plot		G plot		H plot		I plot		J plot	
d	f	d	f	d	f	d	f	d	f	d	f	d	f	d	f	d	f
+	7							0.1	15	0.2	45	0.3	47	0.3	13	0.1	40
												0.3	47	+	7		
2.3	87	1.3	87	4.5	100	3.6	90	3.2	95	1.1	90	4.9	100	4.9	100	1.7	100
												0.1	27				
								+	5								
		+	7			0.1	10			0.3	40	0.1	27	0.3	13	0.1	20
0.7	33	2.9	100					0.8	65	+	5					+	7
		+	40							+	10						
				+	10					+	5	+	7				
+	7															0.1	20
0.1	47	+	58			+	30	0.2	55	0.1	45	+	47	0.1	33	0.4	80
														0.1	13		
+	27					+	20	+	5	+	5	+	20			+	13
+	13							0.1	20	+	15						
+	20	+	7					+	5	0.1	35	+	7	+	13		
		+	12			0.1	10										
								+	5					+	13		
																+	20
						+	10					+	27				
										+	5						
								0.1	20	0.8	95	+	13				
				0.1	10					0.2	60			0.3	53		
2.8	87	3.9	100	0.3	60	2.2	100	2.7	90	3.4	100	1.2	87	0.4	73	3.3	100
				0.2	6												
+	7											+	7			0.1	13
+	13													+	73		
0.8	87	0.4	100	0.3	30	0.7	80	0.3	75	1.0	95	0.9	100	0.9	100	0.7	87
+	7																
														+	13		
0.1	7	+	7							0.1	45						
+	7					0.1	30					+	13	0.1	27		
												0.5	47	0.4	40	0.7	73
						+	10			0.1	10	0.1	13	+	7		
						+	10			+	5	+	7				
								0.2	20								
														+	7		
0.3	60	0.1	47	+	10	0.6	60	0.4	70							+	47
														+	7	+	7
												+	7				
0.5	87	0.3	33	0.1	7	0.1	30	+	45	0.7	95	0.6	80	0.3	40	0.1	20
0.3	33	0.2	53			0.5	60	0.6	85	0.5	75	0.1	7			0.9	87
		+	7									+	7				
		+	7			0.2	10			0.2	15	0.1	27				
								+	5							+	27
										0.1	40			+	7	+	7
						0.2	10										
0.1	33	0.6	80			0.1	40					0.2	33				
0.1	47	0.1	33	0.2	20	0.5	70	0.2	50	0.2	50	0.2	53	0.3	40	0.3	67
0.4	47	0.3	67			0.4	50	0.5	65	+	5					0.1	33
0.7	40	0.6	60	3.4	100	1.4	90	+	20	1.5	75	0.1	20	1.9	87	0.2	13
		+	7			0.1	10			+	15			+	7	0.1	7
0.6	87	1.1	100			0.4	40	0.4	75	+	15	+	13				
0.8	73	+	40	+	30	0.3	80	0.6	75	0.7	95	0.1	53	0.4	93	+	27
						+	10	0.4	15					0.2	7		
		0.4	60					+	10	+	15	0.1	13			+	7
												+	7				
												+	13			+	13
												+	7				
												+	7	+	7		

of frequency.

Table 2. The season when cattle group had entered the researching area.

plot	grazed month
A	June, Oct.
B	June, Oct.
C	June, July, Aug, Oct.
D	July, Oct.
E	June, Oct.
F	June, July, Oct.
G	July, Aug, Oct.

of grazing, but merely show the migration of cattle in a herd into the investigation area. The plot in which the greatest number of cattle migrated was C plot, then followed by the order of F plot and G plot. As viewed the migration of cattle by month, the migration in June was seen in A, B, C and F plots, in July C, D, E, F and G plots and in August both C and G plots. In contrast to such a monthly trend of their migration, the cattle migrated into the entire area during the month of September. The cattle tended to herd in C plot and G plot, because the former had the salt suuply spot for cattle and located nearby the drinking spot and the latter was situated on an airy eminence.

Although the outline of cattle grazing was such as mentioned above, the actual condition of *Miscanthus sinensis* grazed by cattle during the grazing period was given in Table 3 on the basis of investigations of the above-mentioned plots at the end of September. The numerical values in the table were expressed with the average values per 1 m² quadrat. In addition, in order to examine the significant difference of the average values of each item in the table and their mutual relations, an illustration was made with the confidence limit of confidence coefficient 60% as shown in Fig. 2. In Fig. 2 an arrangement was made in the order from the plot greater in the total of stems to the lesser plot. The number of stems grazed in the pasture land, and the number of inavailable stems, number of late sprouting stems and number of ears in the grass fields were arranged in the same ordination as the total number of stems, so that their mutual relations might be known without difficulty. Accordingly, the significant difference lies in a 4% standard in case the lines of each average value was not overlapped with each other. As this rela-

Table 3. Number of stems and height

plat		number of earing stem				number of grazed		
	number of quadrat	total stem number (A)	average stem number per quadrat	earing rate A/D	average height (cm)	total stem number (B)	average stem number per quadrat	rate of inavairable stem B/D
A	20	25	1.3± 1.9	3.9	81.7±23.4	355	17.8±17.6	53.7
B	15	113	7.5± 8.4	15.3	125.6±17.3	349	23.3±13.6	47.3
C	15	3	0.2± 0.8	0.8	52.0± 0	148	9.9±12.7	41.2
D	10	209	20.9±11.1	69.0	192.2±28.2	92	9.2±14.0	31.0
E	10	65	6.5± 6.0	9.7	130.1±18.1	427	42.7±25.9	63.8
F	20	187	9.5±12.4	20.0	133.2±19.0	530	26.5±19.3	58.6
G	20	0	0	0	0	320	16.0±16.6	62.1
H	15	57	3.8± 2.5	2.9	110.7±13.9	1412	94.1±10.1	73.6
I	15	258	17.2± 8.2	22.3	137.6±16.7	792	48.6±16.3	63.1
J	15	57	3.8± 3.9	23.4	112.5±18.4	134	8.9± 8.2	54.8

tionship was made clear in Fig. 2, it needs no explanations here.

As for a clarified point on the number of ears, it should be firstly mentioned that the number of ears was extremely small both in the pasture land and grass fields. Although generally the rate of earing of perennial herb species is defined to be low, the rate of earing in the pasture land ranged 0~69.0% with a considerably wide variation and that in the mowing lands 2.9~23.4% with a somewhat narrow variation. However, the average number of stems in the grass lands showed a wider variation due to the inclusion of plots like J plot. As J plot was too small in the dominance of *Miscanthus sinensis* to be called a mowing land, the plot may as well be regarded as an exception. At any rate, the wide variation of the earing rate may be attributed to the difference of utilization methods such as grazing and mowing and more so to the difference of vegetation. The presence of plots which showed a greater number of ears or a higher rate of earing in the pasture land than in the mowing lands beyond expectations may be ascribed to the maldistributed utilization of the lands as a result of free grazing. The absence of sprouted ears in G plot was due to the destruction by a field fire in June (1955) after regermination in addition to a series of excessive grazing. Therefore, such special conditions should be taken into consideration in case of the plot. At any rate, the small number of ears both in the pasture land and the mowing lands was noteworthy, and that the number of ears in the mowing lands was not considerably gıeat as compared with that in the pasture land was an unexpected phenomenon.

No correlationship was observed between the number of ears and various characters such as the number of grazed stems, number of inavailable stems and late sprouting stems. As there was an rank correlation ($r_s=0.857$, on 5% level with a significant difference) between the precedence of the earing rate and the rank of the dominance, it seems reasonable to say that the earing rate of

of *Miscanthus sinensis* ($\bar{x} \pm s$)

stem	late sprouting stem				total	
average height (cm)	total stem number (C)	average stem number per quadrat	rate of late sprouting stem C/D	average height (cm)	total stem number (D)	average stem number per quadrat
39.5±12.7	280	14.0±13.6	42.4	35.3±12.7	660	33.0±28.2
52.5±13.6	276	18.0±13.5	37.4	41.7±17.1	738	49.2±27.7
18.5± 7.4	208	13.9±10.8	58.0	25.3± 7.6	357	28.8±20.0
80.0±19.7	0	0	0	0	301	30.1±11.7
62.1±17.4	178	17.8±12.9	26.5	31.6±13.3	670	67.0±12.3
63.7±11.2	188	9.4± 6.4	20.7	32.7±15.3	905	45.3±29.5
24.8±12.1	196	9.8± 5.8	37.9	25.4±14.6	516	25.8±20.6
75.5± 9.3	465	31.0±13.6	23.5	34.9±16.2	1934	128.9±39.7
90.7±11.8	170	11.3± 5.8	14.6	25.0±17.6	1157	77.1±19.7
69.4± 9.3	53	3.2± 3.3	21.8	16.3± 9.1	244	16.3±11.2

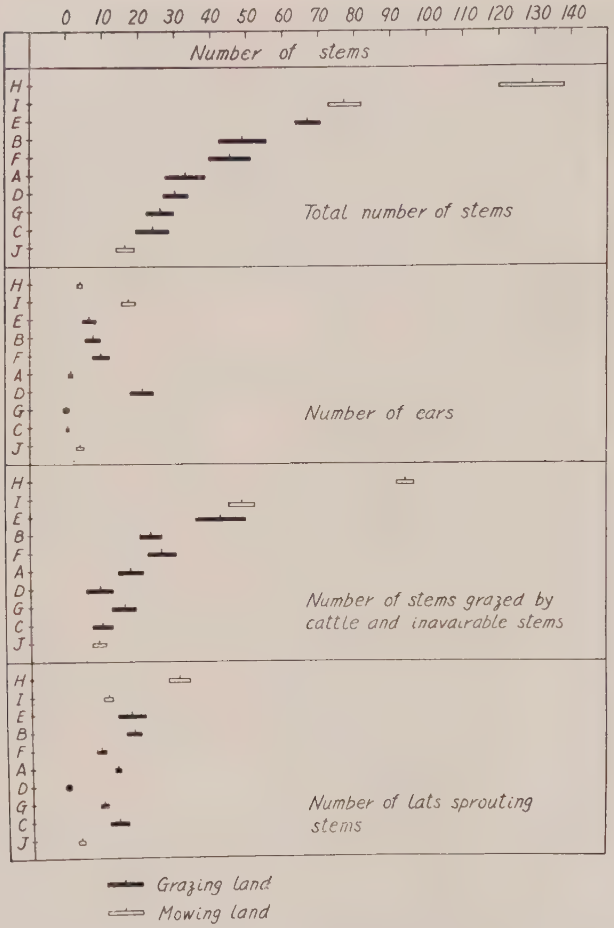

Fig. 2. Relation between total number of stems, number of ears, number of stems grazed by cattle, inavairable stems and number of late sprouting stems (per 1 m^2) of *Miscanthus sinensis*. ($m = \bar{x} \pm t_{0.4}\, s_{\bar{x}}$)

Miscanthus sinensis should be high in the plot with a high dominance of the vegetation, but this relationship could not be held true in case of the inclusion of the mowing lands. This was due to the fact that the rate of earing in J plot became increased and that in H plot lowered as a result of a considerable difference of the total stems between H plot and J plot. Such a phenomenon should be a problem which requires the autoecological researches.

(ii) The number of inavailable stems and the number of late sprouting stems

As for the number of other stems per quadrat, the number of inavailable stems and the number of late sprouting stems were on increase contrary to a small number of ears. The late sprouting stems began to spring up before and after the

heading stage and came into existence intermittently until late in autumn, and the manifestation rate of inavailable stems germinated at a similar time against the heading stems was as high as 54.8~73.6% in the mowing lands. The number of grazed stems in the pasture land should be include potential heading stems, headed stems or late sprouting stems, then it should be higher than the rate of inavailable stems of mowing lands. However the rate of grazed stems in the pasturd land was 31.0~63.8% and showed a wide range of variations, but the rate was not higher in the mowing lands. Withe the exception of J plot, the number of stems was also smaller in the pasture land. However, the range of the variation was somewhat narrower even excluding J plot. In consequence, the number of stems was made uniformalized by grazing. Moreover, the augmentation of inavailable stems (excluding grazed heading stems and late sprouting stems) by grazing may need not be considered. Nevertheless, it seems necessary to make experimental studies on this point by normalization of grazing and amounts of collected grasses.

The rates of late sprouting stems were 0~41.7% in the pasture land and 16.3~34.9% in the grass cutting lands indicating a considerable number of stems of late germination. Although this trait was widely variable in the rate in the same way as the rate of earing, the range of variation in the number of stems was narrow and equalized by grazing.

As viewed the total number of stems on the whole, it was evidently greater in other mowing lands although there were low-graded lands such as J plot. However, the difference between H plot and I plot was conspicuous, the reason for which was unknown. Contrariwise, although the number of stems was smaller in the pasture land, the range of variation was comparatively limited and showed a trend toward equalization due to the similar trend of other characters.

As conjectured approximately by Fig. 2, no correlations among each characters were observed with the exception of the positive correlation between the total number of stems and the number of grazed stems ($r=0.950$, 1% level, significant) in the pasture land. Because of only 3 cases in the mowing lands, no correlations among each characters were observed excepting the rank correlation ($r_s=1$) among the total number of stems, the number of inavailable stems and the number of late sprouting stems. As this resulted from a lack of the cases in number, the accumulation of a number of the material may indicate some correlations. As for the rank correlation, there were correlations between the total number of stems and the number of grazed stems ($r=0.487$, 5% level, significant) and between the rank of dominance of *Miscanthus sinensis* in the entire area and the rank of numbers of stems ($r=0.808$, 5% level, significant). In view of the presence of the positive correlation between the total number of stems and the number of grazed stems in the pasture land, it was understood that cattle tended to graze at a stubs abundant in stems, namely an area with luxuriant plant growth irrespective of the intensity of dominance of

Miscanthus sinensis. This point may need further clarification. In due consideration of the presence of the rank correlation between the total number of stems and the plant dominance, the selection of a mowing lands should be made from areas abundant in the number of stems such as H and I plots. For that reason, the land like J plot should be fallowed.

Besides the above-mentioned, an investigation was made on the plant height of *Miscanthus sinensis* per quadrat in each plot, the avearge values of which were given in Table 3. The grazed stems in the pasture land showed a considerable height of grasses, and the late sprouting stems developed fairly well. Although the growing point of *Miscanthus sinensis* lay in a high position, it was speculated that may grazed only the plant leaves but not to an extent of inhibiting the growing point.

The above-mentioned results were obtained from the supplementary observation on the occasion of the investigation on the number of ears of *Miscanthus sinensis*, from which the authors could know some phase of the ecological condition of *Miscanthus sinensis* in the pasture land.

3. The yield of seeds of *Miscanthus sinensis*

(i) Number of Seeds per ear

The results of investigations on various traits of ears of *Miscanthus sinensis* were given in Tables 4 and 5. B, C and F plots were exempted from the present study. G plot did not show any headings. Ears in each plot (A∼G) of the pasture land included imperfect ears grazed by cattle, but ears in each plot (H∼J) of the mowing lands were all in perfect conditions. The values on the weight of ears, the length of ears and the number of ear branches in the pasture land were rather higher than the mowing lands, with the exception of A plot. Accordingly, it was felt to bear no traces grazed by cattle. Only A plot showed evident small values of all the characters. Such a difference between A plot and each plot of D and E in the pasture land was judged to be due to the periodic difference of graz-

Table 4. Weight, length and number of branches of ear of *Miscanthus sineneis* per ear. ($m=\bar{x}\pm t_{0.05}\,s_{\bar{x}}$)

plot	ear weight (g)	ear length (cm)	number of ear branches	number of examined ears
A	0.1 ± 0.1	8.2 ± 5.6	4.7 ± 2.8	9
B	—	—	—	
C	—	—	—	
D	0.6 ± 0.1	17.2 ± 4.8	15.0 ± 2.0	10
E	0.4 ± 0.2	20.2 ± 6.5	10.0 ± 4.0	8
F	—	—	—	
G	0	0	0	0
H	0.2 ± 0.1	14.7 ± 2.9	7.3 ± 1.6	14
I	0.4 ± 0.1	20.1 ± 5.6	11.7 ± 2.7	15
J	0.2 ± 0.1	10.6 ± 5.4	5.8 ± 3.0	9

note: in A∼G plot included ears grazed by cattle.

Table 5. Number of glumes and seeds, and maturing rate.

plot	number of glumes	number of seeds	maturing rate
A	283.5±189.9	64.3± 48.5	22.8%
B	—	—	—
C	—	—	—
D	847.9±153.5	268.8± 69.7	58.7
E	547.7±233.2	261.9±120.4	31.8
F	—	—	47—
G	—	—	—
H	259.2±115.6	150.5± 64.6	58.1
I	603.6±123.7	317.4± 86.9	52.6
J	228.7±118.3	92.9± 66.2	40.6

noto : in A∼G plot included ears grazed by cattle.

ing aggresion by cattle or the difference of accumulated influence of past utilization. In view of the fact that a number of cattle entered A plot in June and both D and E plots in July, the cattle grazed the growing point in June because of tenderness of stems and tended to feed leaves only in July as a result of hardening of stems.

Putting aside the difference between each plot in the pasture land because of the influence of grazing cattle, the presence of a significant difference between H plot and I plot was considered attributable to the enviromental difference or to the hereditary difference. A significant difference of the length of ears and the number of ear branches was observed between H plot and J plot.

The number of glumes and the number of seeds in the plots of the pasture land excluding A plot showed higher values as compared with the mowing land. However, the maturing rate per ear was generally greater in the mowing land. Accordingly, both the number of glumes and the number of seeds were considered not to be affected by grazing of cattle excepting plot A. As reviewed the difference of each plot of the fallow mowing land, distinct differences were seen between H plot and J plot and between I plot and J plot, but no significant difference was observed between H plot and J plot. Such a difference between I plot and both H and J polts should be attributed to the enviromental or hereditary difference as the above-mentioned weight of ears, length of years and number of sprays.

(ii) The number of seeds per 1 m²

As mentioned earlier, the number of seeds per ear showed the presence of differences among the experimental plots, but the number of seeds in the unit of 1 m² brought about a considerable difference among the plots due to the difference in the number of ears. Although this may be a natural conse-

Table 6. Number of seeds of *Miscanthus sinenis* per 1 m².

plot	average number of ears	number of seeds
A	1.3	186.9± 331.4
B	—	—
C	—	—
D	20.9	5681.0±2509.0
E	6.5	1811.6±1559.5
F	—	—
G	—	—
H	3.4	575.0± 557.1
I	17.2	6553.3±4952.5
J	3.8	563.1± 844.3

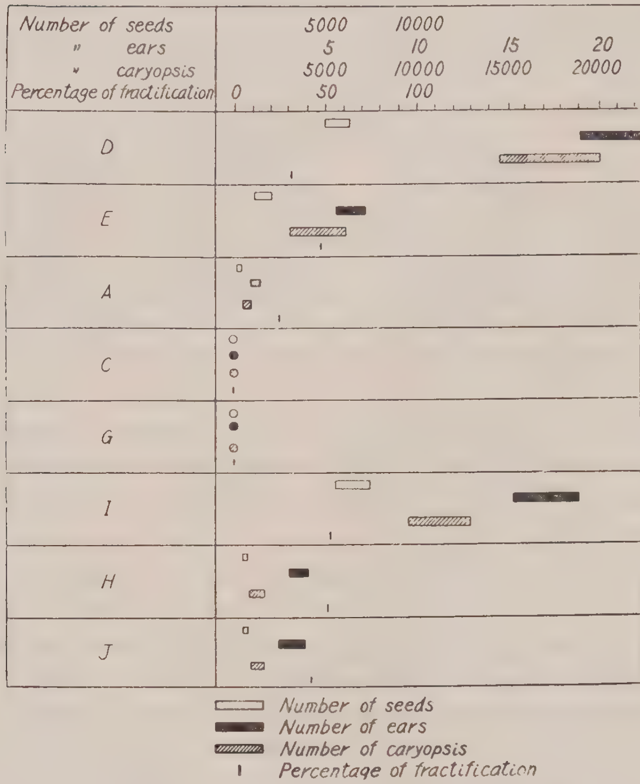

Fig. 3. Relation between produced number of seeds per 1 m² and other characters of *Miscauthus sinensis*.

Table 7. Number of plant seeds migrated in soils.

plot / grass name	grazing land			
	B	C	D	G
Miscanthus sineusis	0	0	10.3±14.1	0.3±0.5
Zoysia japonica	2.9± 5.2	5.0±10.9	0.1± 0.3	0.3±0.6
other *Gramineae*	2.4± 3.5	5.1±10.1	1.5± 0.4	1.3±1.2
Lespedeza sp. and *Microlespedeza* sp.	1.6± 1.6	5.3± 4.5	0.1± 0.4	0.7±1.1
Diervilla hortensis	0.3± 0.7	0.2± 0.4	14.5±20.6	0.8±1.7
Carex sp.	8.8± 8.7	12.4±11.3	0.3± 0.6	3.9±2.8
Halorrhagis micrantha	46.9±60.1	59.3±43.2	0.2± 0.4	6.2±7.6
Lysimachia clethroides	0.3± 0.2	1.1± 1.8	0.3± 0.6	0.7±1.2
Astilbe thunbergii var. congesta	0	2.2± 4.9	0	0
unknnown species A	7.9± 5.7	15.3± 7.4	3.1±4.7	8.5±6.8
〃 B	51.9±41.4	16.7±11.1	0	4.4±1.8
〃 C	1.9± 1.9	1.4± 1.8	0.5± 1.1	0
other unknown species	4.1± 5.7	2.9± 2.4	16.1± 9.9	4.4±5.3
total	1934	1902	723	434

note: number of seeds are averaged of 15 plots.

quence, these relations were illustrated in Table 6 and Fig. 3, by which the dominating effect of the number of ears upon the presence of significant differences of the respective average values and the above-mentioned numbers of seeds and glumes can be seen distinctly. The productivity of a large number of seeds in the pasture land, as produced 187 grains in A plot and 568 grains in D plot, may be said enough for the maintenance of generations. As *Miscanthus sinensis* takes a short period of dormancy and indicates 50～80% germinating rates, the domination of *Miscanthus sinensis* in grasslands of this country can be understood without difficulty.

4. Migration of *Miscanthus sinensis* seeds

Although the production of seeds per unit acreage was, as mentioned above, made clear to be enough for the maintenance of generations, it is necessary to know the actual condition of migration of the seeds which were effected by winds, rainfalls and birds and animals (including domestic animals) as well as by field fires. Consequently, seeds scattered in soils and on the surface of the earth were detected by the above-mentioned method, the results of which were given in Table 7. In the table a *Pteridium* dominant plot with naught in the number of ears was added newly to K plot, and J plot was subdivided into (J_f) which underwent a field fire and (J) not subject to it.

The detection of seeds was carried out not only on seeds of *Miscanthus sinensis* but also seeds of other grass species and shrubs. The insertion of leguminous plants en bloc in the table included *Lespedeza biocolor*, *Microlespedeza striata* and *Lespedeza sericea*. Besides, unknown species A, B and C were denoted separately because of their abundance, although these unknown species and "others" were entirely ambiguous.

Relatively old seeds and scorched seeds by a field fire were, though small in number, included in the detected seeds. Although the scorched seeds seemd

(per circle of 10 cm in diameter, $\bar{x}\pm s$).

	mowing land				average
K	H	I	J	J_f	
2.8± 3.2	1.0± 0.9	4.0± 4.9	1.1±1.0		
2.5± 3.6	0	0.1± 0.3	0.3± 0.6	0.3±1.1	
8.2± 6.9	1.1± 0.7	1.0± 1.3	0	0.4±6.9	
5.8±14.3	0.9± 1.2	0.9± 1.0	0.5± 0.7	0.1±0.2	
1.3± 4.4	16.9±11.5	9.3± 9.4	4.4± 3.8	0.3±0.4	
2.7± 2.4	7.1± 7.1	2.5± 2.3	6.9± 5.3	4.1±5.0	
4.3±10.1	8.9±17.9	6.2±14.2	34.8±50.1	5.3±6.2	
0.5± 1.2	0	0.1± 0.4	0	0.4±0.4	
0	0	0	1.1± 2.9	0	
9.7± 8.6	4.5± 3.7	9.1±10.5	6.1± 4.6	0.4±0.8	
11.3±10.8	3.4± 9.4	0	0	0	
0.6± 1.0	5.7± 4.4	1.6± 2.4	94.9±65.4	6.8±8.7	
6.3± 4.2	3.5± 4.6	4.4± 4.5	2.5± 2.6	1.2±0.2	
840	804	594	2294	358	1098.1±723.1

almost incapable of gerneration, such treatment was made in view of the purpose of the present study which aimed not to examine the capacity of germination but to review the distribution of seeds.

What comes in question here is the extent of detection of seeds on the surface of the soils and in soils against the number of produced seeds. This relation was shown in Fig. 4 with the confidence limit of their actual numbers. Though not

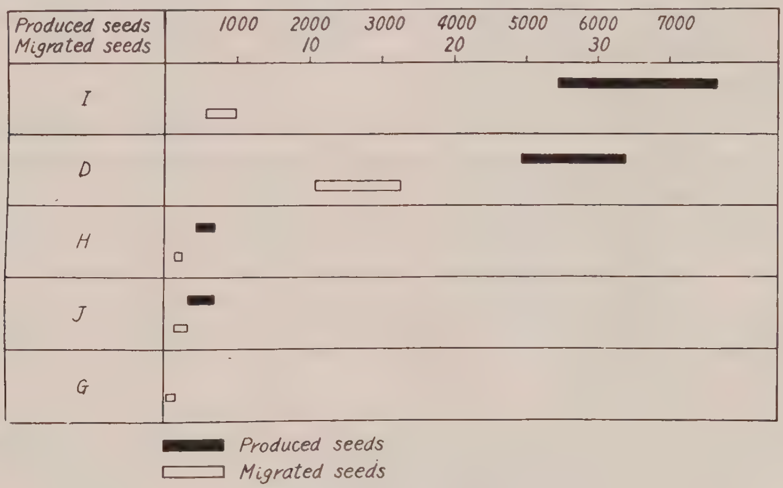

Fig. 4. Relation between number of produced seeds and migrated seeds of *Miscanthus sinensis* ($m=\bar{x}\pm t_{0.4}S_{\bar{x}}$).

illustrated in the figure, in B plot the number of migrated seeds was naught though the number of ears average 7.5 heads, and in K plot the average number of 2.8 seeds was detected in spite of the absence of ears in the plot. Among the plots in the figure, the migrated seeds averaged 0.3 were detected in G plot against the naught in the number of ears. As viewed these results and the trend of Fig. 4, the

Table 8. Number of produced seeds and migrated seeds of *Miscanthus sinensis*. (per circle of 10 cm in daimeter).

plot	average number of ears	number of produced seeds (a)	number of migrated seeds (b)	b/a %
A	1.3	1.5	—	—
B	7.5	—	0	(−)
C	0.2	—	0	(−)
D	20.9	44.6	10.3	23.1
E	6.5	14.2	—	—
F	9.4	—	—	—
G	0	0	0.3	(+)
H	3.8	4.5	1.0	22.2
I	17.2	51.4	4.0	7.8
J	3.8	4.4	1.1	25.0
K		0	2.8	(+)

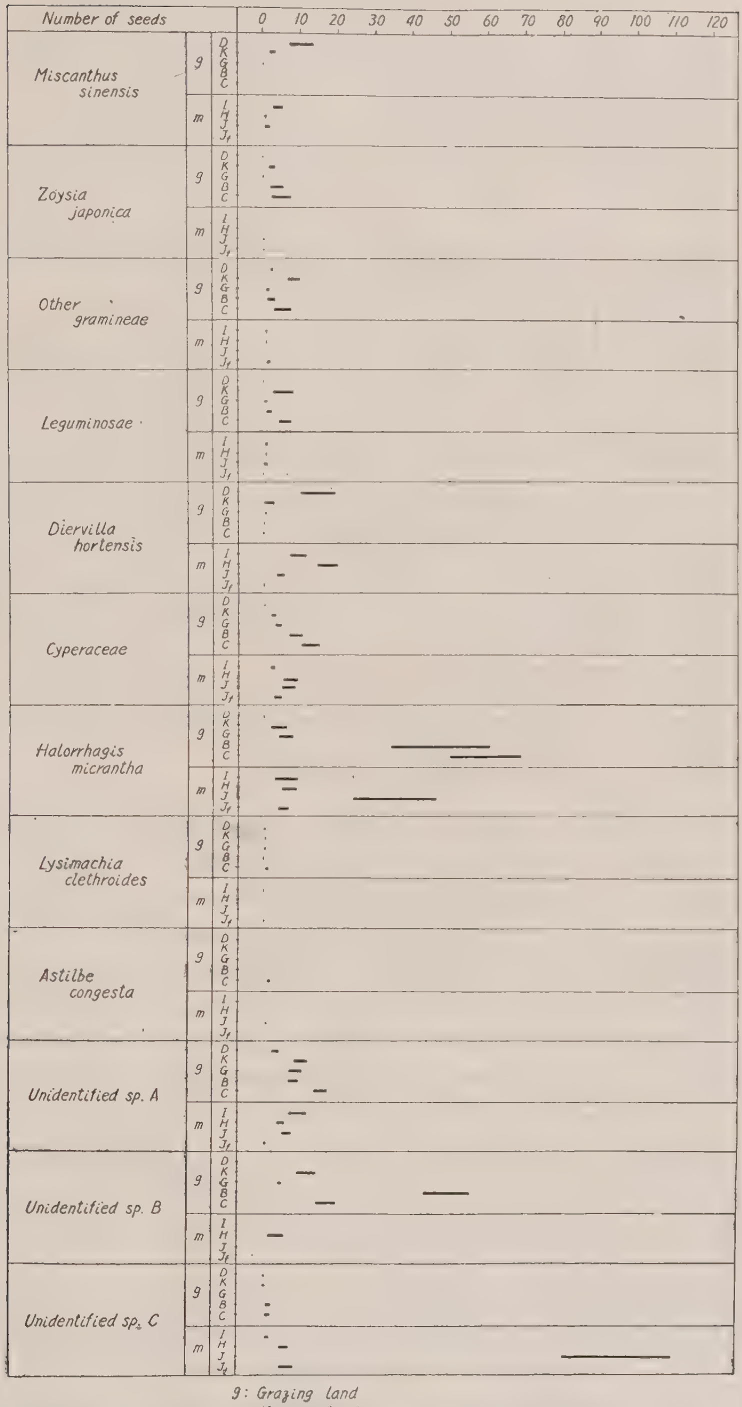

Fig. 5. Migrated seeds in soil ($m=\bar{x}\pm t_{0.8}\, s_{\bar{x}}$).

number of migrated seeds were not always in parallel to the number of produced seeds. Therefore, it may be safely said that the quantity of migrated seeds does not necessarily correspond with the quantity of produced seeds.

As the detection of migrated seeds in the same plot against the number of produced seeds was expressed with % by making the unit acreage identical, the ratios between the former and the latter were 23.1% in D plot, 22.2% in H plot, 7.8% in I plot and 25.0% in J plot. As a result, the detection ranged as much as 0∼25% (cf. Table 8). As a reverse phenomenon, migrated seeds were, though few in number, detected in the plots which showed no earing.

The detection number of seeds other than *Miscanthus sinensis* was considerably numerous, and the detection of 1098.1 seeds in the average from an acreage of 78.5 cm^2 reflected on a hard competetion in the natural grassland. Although a number of plant species were detected besides 10 known species of plants, the names of thess species were unknown. Besides *Miscathus sinensis*, those which were known were seeds of *Zoysis japonica*, *Diervilla hortensis*, *Halorrhagis micrantha*, *Lysimachia clethroides*, *Astilbe thunbergii.*, *Lespedeza bicolor*, *Microlespedeza striata*, *Lespedeza sericea*, *Gramineae* family and *Cyperaceae* family. As these seeds did not necessarily correspond with vegetations in the respective plots, they migrated apparently from other plots.

Although no correlation was seen between the rank of quantity of detected seeds of *Miscanthus sinensis* and the rank of dominance of the plant, an interesting relationship was observed between the number of *Miscanthus sinensis* seeds and seeds of some grass species and shrubs. As can be seen in Fig. 5, there were a negative correlation ($r=-0.810$, 1% level, significant) between the seeds of *Miscanthus sinensis* and *Halorrhagis micrantha*, similarly a negative correlation ($r=-0.912$, 1% level, significant) between the seeds of the plant and *Cyperaceae* and a positive correlation ($r=0.732$, 5% level, significant) between the seeds of the plant and *Weigela hortensis*. Although the direct reflection of the mutual relation between these seeds on the vegetation can not be predicted, *Halorrhagis micrantha* is a grass species abundant in a *Zoysia type grassland*, and plants of *Cyperaceae* family are rarely found in a grassland dominated by *Miscanthus sinensis*. The same trend is observable in case of *Halorrhagis micrantha*. Seeds of *Zoysia japonica* are not related so closely with *Miscanthus sinensis* as to indicate a corelation, but its increasing tendency in pursuance of the decrease of *Miscanthus sinensis* seeds may indicate the sere of vegetative succession in the natuaral grassland of this country.

5. Natural germination of seeds of *Miscanthus sinensis*

The investigation on the number of seeds of *Miscanthus sinensis* in natural germination resorted to the method of counting the number of young plants then living in October. The survey was made only in J plot, which was subdivided into the section subject to a field fire and the non-fired section, and further into the upper and lower sides of the slope land. The results of investigations of 10 places

Table 9. Number of young plant of *Mircanthns sinensis* per 1 m^2 cirelar area. $m = \bar{x} \pm t_{0.05} S_{\bar{x}}$.

	plot of fired	plot of non-fired
upper sides of slope	30.7±8.0	37.8±18.4
lower sides of slope	10.3±3.4	12.4± 6.9

each from the subdivided sections were shown in Table 9.

In short, the numerousness of the natural germination on the upper side of the slope land and its scarcity on the lower side, and the non-intervention of a field fire were recognized in view of the presence of a significant difference at 4% level. The J plot is situated on the southern slope land on a strip of creases in a mountain-range, half of which was subject to to a field fire. The selection of a series of the investigation spots was made at a right angle to the slope land in the lower region nearby the bottom of the valley and the upper side of some 20 m only ranging over the section branded with a field fire and the non-branded section. The manifestation of such a evident difference between the upper and lower sides of the slope land, and moreover in the upper side in comparison with the lower side were beyond expectations. The reason for the above-mentioned difference was not made clear. As for the non-intervention of a field fire, the result was also contrary to expectations, although it was related with the intensity of a field fire.

IV. Summary

The general aspect of plant successions in *Bokuya* (the natural grassland in Japan) has been already made clear, but it may be said that its succession mechanism is unknown at all. The authors made an attempt to clarify the succession mechanism of *Miscanthus sinensis*, one of the most important grass species in *Bokuya*, through a consistent study of its phenomena such as productivity of seeds, migration of seeds, natural germination and growing conditions in 11 plots under the different dominance of *Miscanthus sinensis*.

1. The number fo ears of *Miscanthus sinensis* per 1 m^2 was exceedingly small. However, it was apparent that the grazing of cattle would not lower the number of ears in the pasture land.

2. Though small in the number of ears, inavailable stems were numerous. The total number of stems was generally greater in mowing land rather than in pasture land. In view of the presence of a positive correlation between the total number of stems and the number of stems grazed by cattle, it was known that cattle tended to graze at a stubs abundant in stems regardless of the quality of the plants.

3. As a tendency of cattle, they grazed leaves preferably and left stems, then some of lefted stems kept growing and attained head-sprouting.

4. The yield of seeds per ear was considerably variable by plot. In addition, the ripening rate was low.

5. Although the yield of seeds per ear was variable remarkably, the yield of seeds per 1 m² was decided by the number of their ears. The yield of seeds per 1 m² numbered 187～568 grains in the pasture lands and 563～6,553 grains in the grass fields. Such productivity of seeds was enough for the maintenance of generations.

6. The migration number of seeds did not necessarily correspond with the yield of seeds in a given plot. In other words, there were cases in which none of seeds was detected in a plot which yielded seeds, and vice versa. In general, the migration number of seeds was no more than 7.8～24.9% of the yield of seeds.

7. Besides *Miscanthus sinensis* seeds, seeds of about 20 species of grasses and shrubs were detected in soils, and their revelation did not necessarily take place in concert with the vegetation of a plant community. There were observed a negative correlation beteen the seeds of *Miscanthus sinensis* and the seeds of *Halorrhagis micrantha* and *Cyperaceae*, and a positive correlation between the seeds of *Miscanthus sinensis* and *Weigela hortensis*.

8. After natural germination of seeds of *Miscanthus sinensis*, the number of thier young plants which lived by autumn was numerous on the upper side of the slope land and scarce on the lower side. Meanwhile, the non-intervention of a field fire was observed. The number of these young plants averaged 25% of the number of migrated seeds, and the ratio against the yield of seeds was as considerably low as 6 %.

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